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L. O. HOWARD, Entomologist and Chief of Bureau.

THE SPRING GRAIN-APHIS OR "GREEN BUG."

BY

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CEREAL AND FORAGE INSECT INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 28, 1911.

Sir: I have the honor to transmit herewith for publication the manuscript of a bulletin on the spring grain-aphis, popularly known as the "green bug," by F. M. Webster and W. J. Phillips, of this bureau. The investigations upon which this bulletin are chiefly based began under a special appropriation made by Congress in the spring of 1907. These investigations have been continued without interruption up to and including 1911. Preliminary reports upon the work were published in Circulars Nos. 85 and 93. The present report, however, is a complete record of the entire investigation, including many aspects of the problem not before touched upon in any publication relating to this group of insects. I recommend the publication of this manuscript as Bulletin No 110 of the Bureau of Entomology.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE SPRING GRAIN-APHIS OR "GREEN BUG."

INTRODUCTION.

Investigations of the spring grain-aphis, or "green bug" (*Toxoptera graminum* Rond.) (fig. 1), in America were first begun by the senior author in the year 1884, at Oxford, Ind., where the insect was accidentally introduced with, or had in some obscure way gained access to wheat plants which had been transplanted from the open to rearing cages standing out of doors on a blue-grass lawn (June 6) and used in carrying out investigations on the greater wheat strawworm (*Isosoma grande* Riley). At that time the insect gave no indication of its present economic importance and for this reason was not then given special attention.

In 1890, when the pest really first gave evidence of its capabilities as a grain destroyer over a wide range of country, the senior author again took up its study, gaining considerable additional knowledge of its habits and of the influences of temperature and season upon its abundance. (See Diagrams I–V.)

The less serious outbreak of 1901 was not investigated and our information relative to it is derived chiefly from correspondence of the bureau for that year.

The incipient outbreak of 1903 was reported from Texas by Prof. E. D. Sanderson, at that time State entomologist, and from South Carolina by correspondents of the bureau.

The last and most disastrous outbreak of all, that of 1907, was investigated not only by both of the authors, but by Mr. C. N. Ainslie, who began his work on the species at Summers, Ark., on March 18, continuing the investigation almost uninterruptedly through the summer, working over the country from central Oklahoma northward to Canada, and returning to Washington in September. The junior author spent April, May, and a portion of June in Oklahoma and Kansas in field investigations, returning to Richmond, Ind., where he was at that time located and where he took up a systematic study of the insect, its habits, and development—a study which has been continued up to the time of preparation of this manuscript for publication. Messrs. E. O. G. Kelly and T. D. Urbahns spent much time in a study of the parasites; indeed, most of the assistants in cereal and forage insect investigations have

contributed more or less to our knowledge of the pest and its natural enemies, and throughout the following pages credit has been given

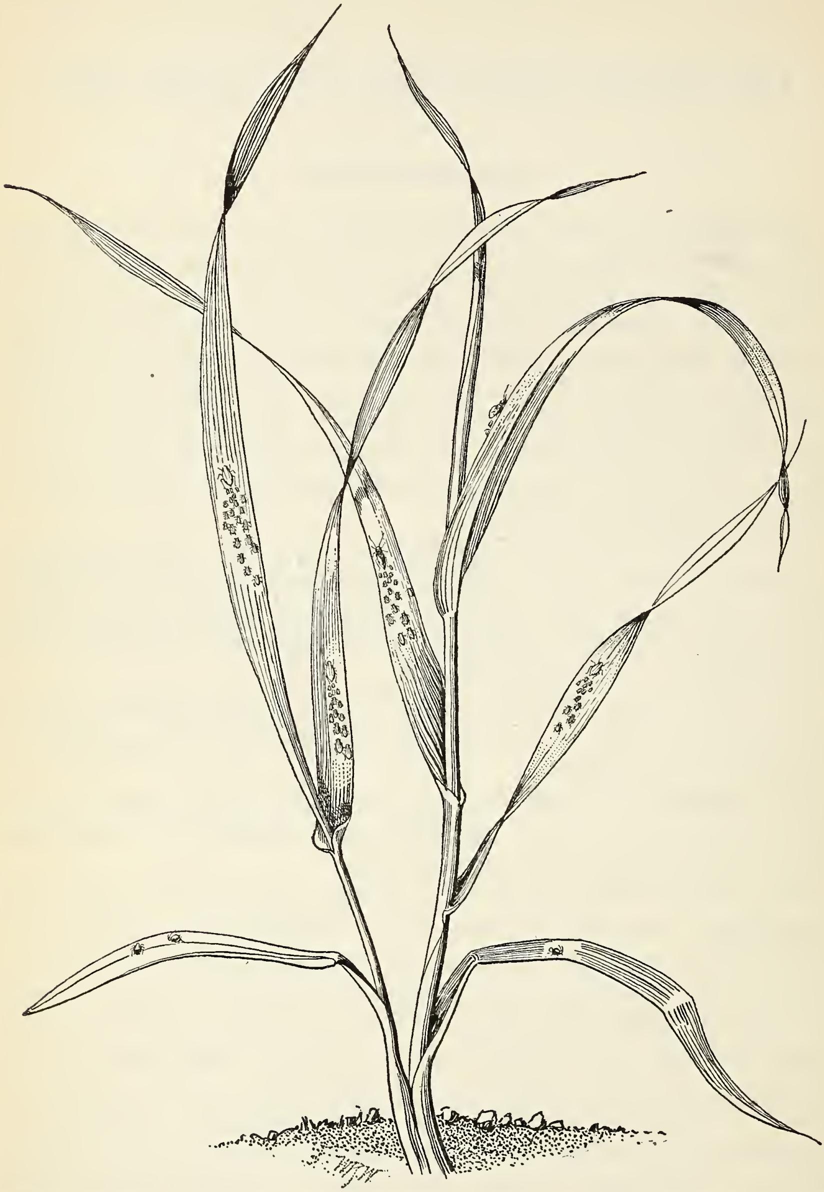

FIG. 1.—The spring grain aphis (*Toxoptera graminum*): Wheat plant showing winged and wingless viviparous females with their young clustered on the leaves, and a few parasitized individuals on lower leaves. About natural size. (Original.)

each individual where possible to do so. For a critical, technical study of the parasites of the species, credit should be given Mr. J. C. Crawford, assistant curator, Division of Insects, U. S. National

Museum, and Mr. H. L. Viereck, expert, Bureau of Entomology, who are specialists in the parasitic Hymenoptera.

During the winter of 1907–8 Congress provided the sum of $10,000 for carrying on these investigations; otherwise this work would have been impossible.

EARLIEST OBSERVATIONS ON THE INSECT IN AMERICA.

The first examples of *Toxoptera graminum* to be found in America and identified as such were probably collected with the oats plants which they were destroying by Mr. H. S. Alexander, of Culpeper, Va., on June 15, 1882. A letter in the files of the Bureau of Entomology, written on the above date and addressed to Hon. George B. Loring, then Commissioner of Agriculture, stated that he, Mr. Alexander, was sending by that evening's mail specimens of an insect which had almost entirely destroyed the oats crop in his neighborhood. But he very evidently neglected to indicate on or within the package the name and address of the sender. Under date of June 17, 1882, the records of the old Division of Entomology show, however, that a package of oats or wheat plants—exactly which could not be determined by the person making the examination—were received on that date, badly infested by what was determined as *Toxoptera graminum.* As there was nothing on or within the package to indicate the source from which the material came, the locality has since remained in obscurity. Upon a recent examination of the old letter files, the communication of Mr. Alexander was found and a reply thereto by Dr. Riley, dated July 7, 1882, stating that the communication had been received from Mr. Alexander, but that the specimens referred to by him had not arrived. As the Division of Entomology did not have these specimens before them when Mr. Alexander's letter was received, or did not connect these specimens with his letter it was assumed that the species was the well known *Siphonophora avenæ* Fab., a name at that time applied to what is now called *Macrosiphum granaria* Buckt. Evidently the connection between the letter and package was never investigated, as the insects in the package proved to be Toxoptera. It is significant that of the eight communications received at the Department of Agriculture about that time, from various points in Virginia and including also one from Maryland, all relating to the wheat louse, this one from Mr. Alexander is the only one not shown to have been accompanied by specimens, and also it was the only communication in which reference was made to the destruction of oats, all of the other letters alluding to insects found infesting wheat or rye, which were probably *M. granaria* Buckt. Without a doubt, therefore, the letter of Mr. Alexander refers to the package received June 17, 1882, without

name or address of the sender. A correspondent of the "Country Gentleman," writing over the initials G. C., from Chrisman, Rockingham County, Va., about 50 miles west of Culpeper, under date of June 16, 1882, makes this statement:

> Wheat looking well and promising, but there is a little green bug on it that may injure it. This same little green fellow is ruining the oats in this neighborhood, and has already destroyed them entirely in many localities.[1]

It is not at all surprising that Toxoptera and Macrosiphum should have been confused at that time, as the former species was yet unknown in the country and its presence could only be determined from winged individuals. In all of the succeeding outbreaks of Toxoptera it has been more or less difficult to separate the wingless individuals of these two species definitely from each other, even experts having been often at fault where there were only immature individuals upon which to base a separation. In this connection Mr. B. F. White, writing from Mebane, N. C., January 28, 1890, complaining of damage at that time to oats in his locality by Toxoptera, specimens of which accompanied his communication, stated that the same insect appeared in 1882, in May. So, then, it seems quite likely that, while the discovery was first made at Culpeper, Va., the insect occurred over a considerable area of country in Virginia, extending southward into northern North Carolina (see fig. 2; Diagram I, p. 15).

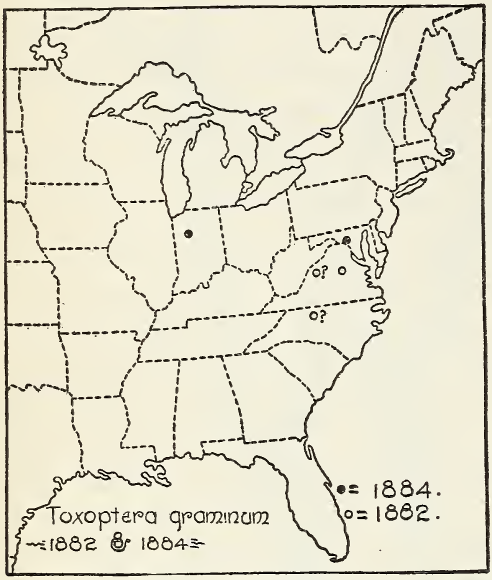

FIG. 2.—Map showing the locality from which the spring grain-aphis was received in 1882 and the two additional localities where it is probable that it also occurred in injurious numbers in that year; also the two localities where it was found in 1884. (Original.)

From the foregoing it would appear that at this early date there was a more or less destructive outbreak of this pest in the southern Atlantic States. That the species was confined to this area, however, is hardly possible, and indeed it is not beyond possibility that damage to oats may have extended much farther westward, though we have been unable to find definite proof to that effect. The all-important temperature influences are also indicated.

[1] Cultivator and Country Gentleman, vol. 47, p. 498, June 22, 1882.

On June 7, 1884, Mr. Albert Koebele found this species infesting wheat plants at Cabin John Bridge, situated in Maryland a few miles above Washington, and about July 1 of the same year the senior

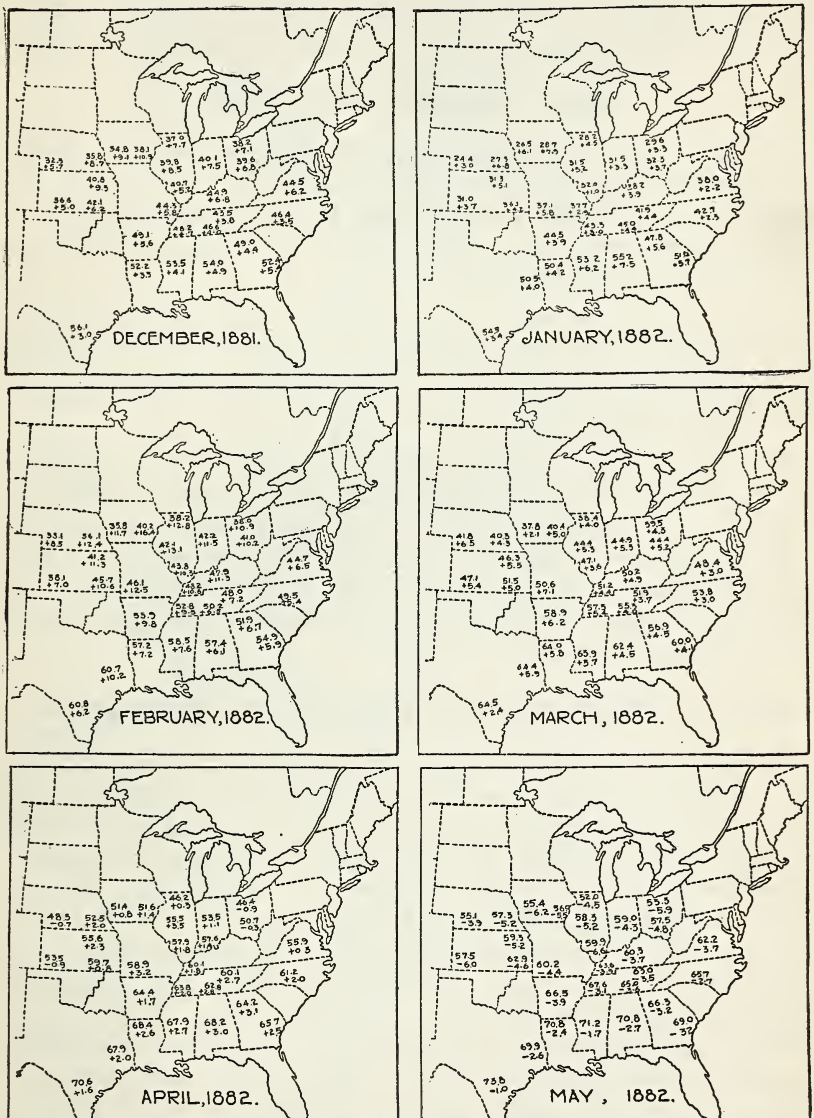

DIAGRAM I.—Maps of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and, –, below), for the critical period December, 1881, to May, 1882; above normal (+) in winter and below normal (–) in spring being favorable for outbreak of spring grain-aphis. (Original.)

author found it in one of his rearing cages, placed out of doors at Oxford, Ind. (see fig. 2). In the latter instance the species showed a preference for wheat plants over those of rye, and in September it

was common in the fields on volunteer wheat plants in the same locality and also about La Fayette, Ind. In some fields it was observed breeding on the young growing wheat throughout the autumn and early winter up to December 13. On the 30th of December it was still to be found alive in the fields, though not in great abundance.

EARLY RECORDS IN EUROPE.

The first exact knowledge we have of this insect is its occurrence in excessive abundance about Parma, Italy, in 1847. Five years later, in 1852, Rondani, who described the species during this year, wrote to Prof. Bertoloni under date of June 14, also from Parma, relative to the insect as follows:

> We have in our city an innumerable number of insects of a species of the Aphis genus, of Linnæus, of the order of Hemiptera. Sometimes and in certain places the number of these insects flying in clouds in the air has been so great as to render them troublesome to people, entering the nose, eyes, and even the mouth, when one can not think how to protect oneself from them.

Elsewhere in this letter Rondani stated that he had never been able to find it on any but graminaceous plants, where it nestled on the leaves. In commenting on this letter of Rondani, Prof. Bertoloni took occasion to say that "innumerable specimens of the *Aphis graminum* Rondani are seen in the streets of the city of Bologna, and these have several times entered my nose and eyes when passing rapidly along the canal of Reno."

KNOWN DISTRIBUTION IN THE EASTERN HEMISPHERE.

Besides these occurrences in Italy and Hungary (see fig. 3), in 1884 Dr. G. Horvath records an attack on oats in central Hungary, which took place in June, 1883, and 10 years later, in 1894, Prof. Carl Sajo records a second outbreak among growing oats, also in Hungary.

Schouteden, in 1906, records the species from Belgium, but gives no further data except that it affects the Graminaceæ.

Under date of October 7, 1907, Mr. H. Neethling, chief of the horticultural and biological division, department of agriculture, Bloemfontein, Orange River Colony, South Africa, in a letter addressed to the United States Department of Agriculture, stated that the wheat aphis was one of the greatest scourges with which the farmers of his colony had to contend, nearly the whole crop having been destroyed by it for several consecutive seasons. Again, under date of September 28, 1908, the same gentleman stated that the pest had been particularly active that season, it being estimated that more than 50 per cent of the entire wheat crop of the colony had been destroyed by its ravages. This latter communication was accompanied by specimens of *Toxoptera graminum* as well as a small

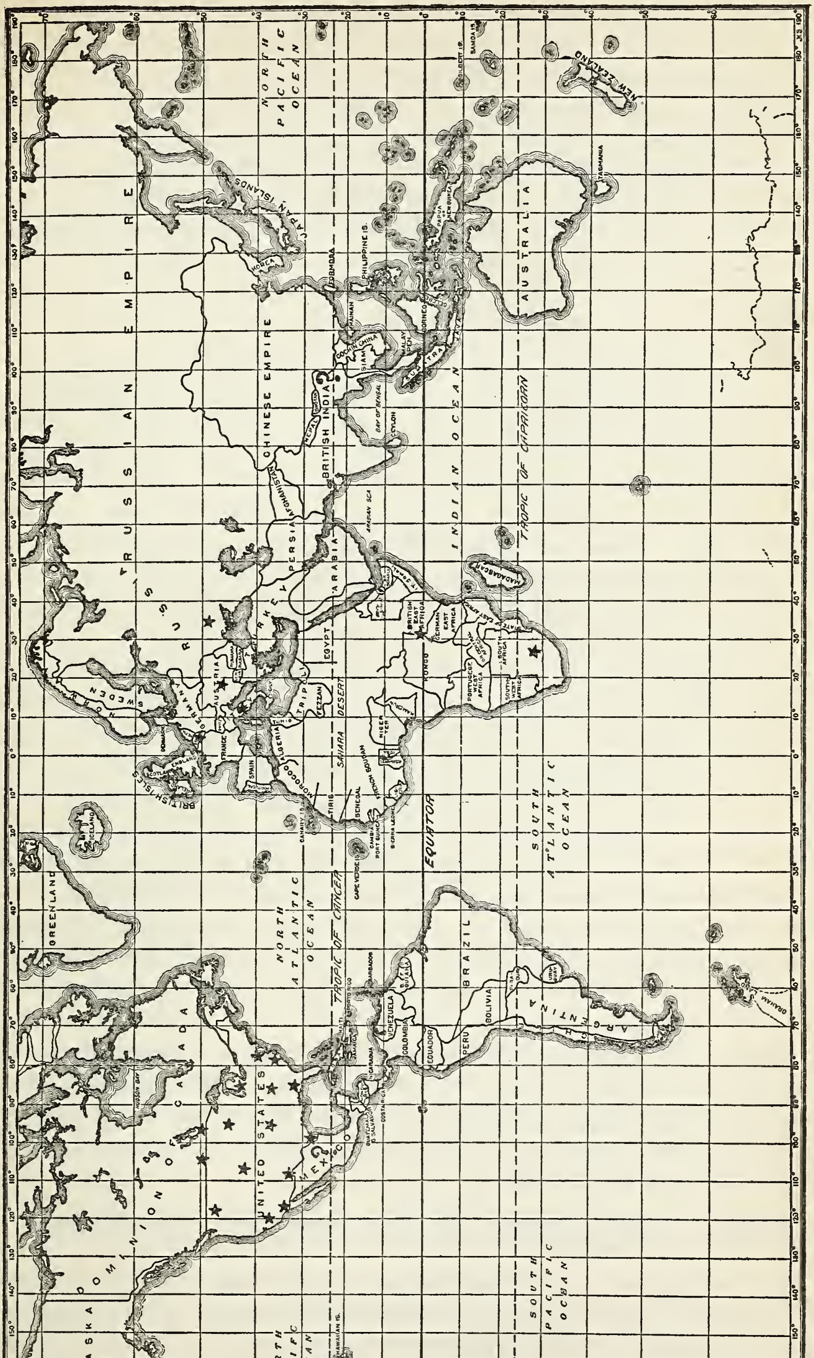

FIG. 3.—Map showing the distribution of the spring grain-aphis in both the eastern and the western hemispheres. Known localities are indicated by an *; suspected localities by ?. (Original.)

hymenopterous parasite, *Aphidius* sp., and larvæ and adults of a coccinellid, *Adalia flavomaculata* De G., both of which were observed destroying the aphidids. Under date of October 1, 1910, Mr. C. P. v. d. Merwl, assistant biologist of the same department, stated that another outbreak of the pest had taken place that spring and considerable damage had been done. In this communication the statement was made that the writer had personal knowledge of the occurrence of the species during the past 20 years, and that farmers had stated that they had always known of its occurrence in that country. It had, however, become seriously destructive during recent years and at that time farmers were being forced to give up growing wheat extensively on account of its ravages.

In the Agricultural Journal of India [1] Mr. H. Maxwell-Lefroy, government entomologist of British India, stated that the wheat aphis (*Toxoptera graminum*) seeks shelter in the depths of the grass roots; in different ways insects adapt themselves, but these had probably done it gradually, moving in from cooler to hotter areas step by step. From the illustration of this insect accompanying this statement and from specimens later submitted by Mr. Maxwell-Lefroy, it has been found impossible to determine the species involved as *Toxoptera graminum*.

On November 25, 1910, Mr. William Sewall, of Njoro, British East Africa, called at the office of this bureau to complain of the ravages of a green louse or fly which attacked and destroyed wheat on his farm in the above-named locality, situated almost directly on the equator in a prairie-like country at an elevation of 7,000 feet above sea level. A communication was received from Mr. Sewall bearing date of August 22, 1911, accompanied by specimens, in which he stated that the ravages now extend over an area of 700 acres. He also stated that his neighbor, Lord Delamere, who had not been troubled previously, experienced severe losses over an area of about 4,000 acres. The specimens accompanying Mr. Sewall's letter have been determined as *Toxoptera graminum* by Mr. J. T. Monell.

With these records of the known and probable distribution of *Toxoptera graminum*, it does not seem improbable that if the minute insects of the family Aphididæ were carefully studied this species would be found generally diffused throughout the temperate and tropical regions of the world.

KNOWN DISTRIBUTION IN THE WESTERN HEMISPHERE.

With reference to the distribution of this insect in the Western Hemisphere (see fig. 4), it can be said that it has only been studied in the United States. Its occurrence in western Canada is well established. On the south it is known along the Mexican border from the Gulf of

[1] "Imported insect pests." Agricultural Journal of India, vol. 3, part 3, pp. 243-244, July, 1908.

Mexico almost to the Pacific Ocean. It has not actually been found in Mexico and no one has searched for it there. Wheat in Mexico is said to have been injured by a "green louse," and it is reasonable to suppose that the insect may occur far to the southward of its present known range of distribution. Its entire absence from eastern Canada and northeastern United States, except in eastern Massachusetts near Boston, where it seems to have been found by Mr. Paul Hayhurst in September, 1908, will be noted.

THE OUTBREAK OF 1890.

(Fig. 5, p. 20; Diagram II, p. 21.)

Up to the year 1890 in this country the very destructive nature of this insect had not yet become apparent; hence it had not received the close attention that, as we now understand, it justly deserves.

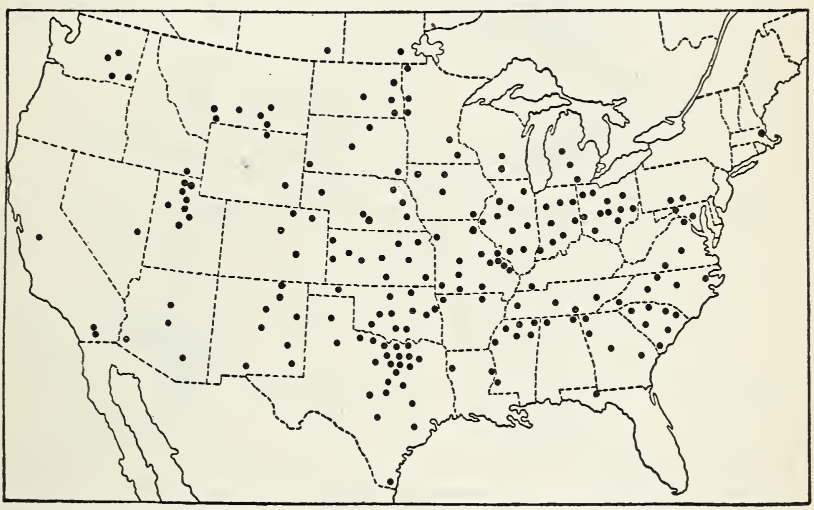

FIG. 4.—Map showing the known distribution of the spring grain-aphis in the United States and Canada. (Original.)

While the senior author was and had been engaged in grain-insect investigations in Indiana during the six years following its discovery by him at Oxford, the species was not looked upon as one of those deserving especial attention; therefore from 1884 to 1889 no notes were made upon it, and no references to it are to be found in the correspondence of the Division of Entomology. Mr. J. T. Monell, now of this bureau, however, has specimens in his collection from Illinois, taken in 1886.

During November and December, 1889, the insect was again observed in such abundance in fields of young wheat about Lafayette, Ind., as to attract the attention of the senior author, who found it repeatedly on young wheat in the fields during the entire winter. The influences of mild or high temperatures during winter, especially

in the South, and low temperatures during spring months were carefully observed and set forth in a report published later.[1]

As early as the middle of January, 1890, it was reported by Mr. P. C. Newkirk as killing the young wheat about Jalapa, Tenn., and on the 26th of the same month Mr. B. F. White, of Mebane, N. C., reported it as ruining both wheat and oats in his neighborhood. Mr. J. L. Fooks, writing on the same date from Era, Tex., stated that the insect had played sad havoc with the wheat in his neighborhood, while April 7 Mr. D. J. Eddleman, Denton, Tex., complained of the pest destroying the wheat. Writing in 1901 Mr. H. K. Jones, Valley View, Tex., stated that the insect appeared there about 10 years pre-

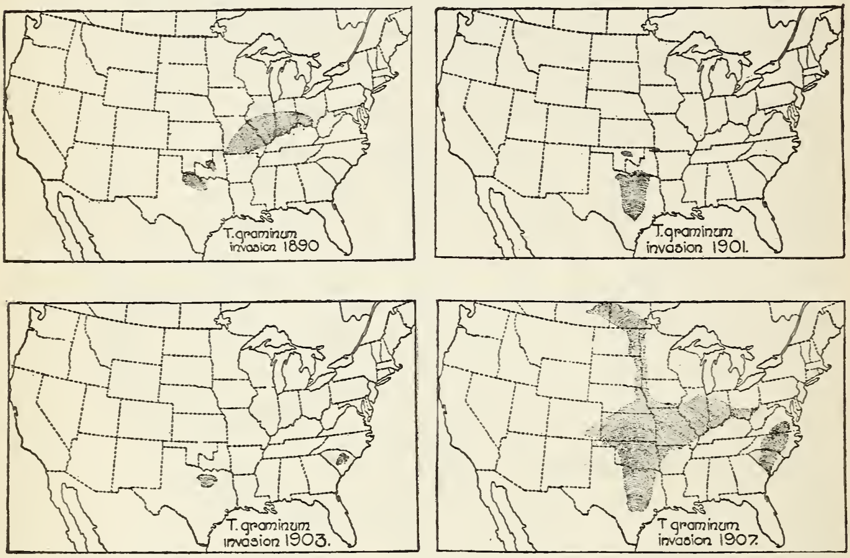

FIG. 5.—Maps showing areas covered by outbreaks of the spring grain-aphis during the years 1890, 1901, 1903, and 1907. (Original.)

vious and killed about all the wheat in the county. From this and other correspondence, accompanied by specimens, it seems that wheat in Cooke, Grayson, Collins, Denton, and Wilbarger counties, Tex., was more or less damaged by this pest.[2] No reports are at hand showing injuries to wheat or oats in what was at that time Oklahoma and Indian Territories, for the reason that little of either of these grains was at that time grown. But we now know that grains were not essential to its presence in that country.

In Missouri the situation was more acute and strongly indicates that the pest was present in southeastern Kansas and northern Arkansas. According to Mr. Monell's notes, the pest completely

[1] Insect Life, vol. 4, pp. 245–248, 1892; Bul. 22, Div. Ent., U. S. Dept. Agr., pp. 64–70, 1890; Yearbook U. S. Dept. Agr. for 1907, pp. 239–241.

[2] Insect Life, vol. 3, p. 75.

destroyed a field of 60 acres of oats belonging to Hon. Roland Hazard at Mine Le Motte, situated about 100 miles south of St. Louis, Mo.,

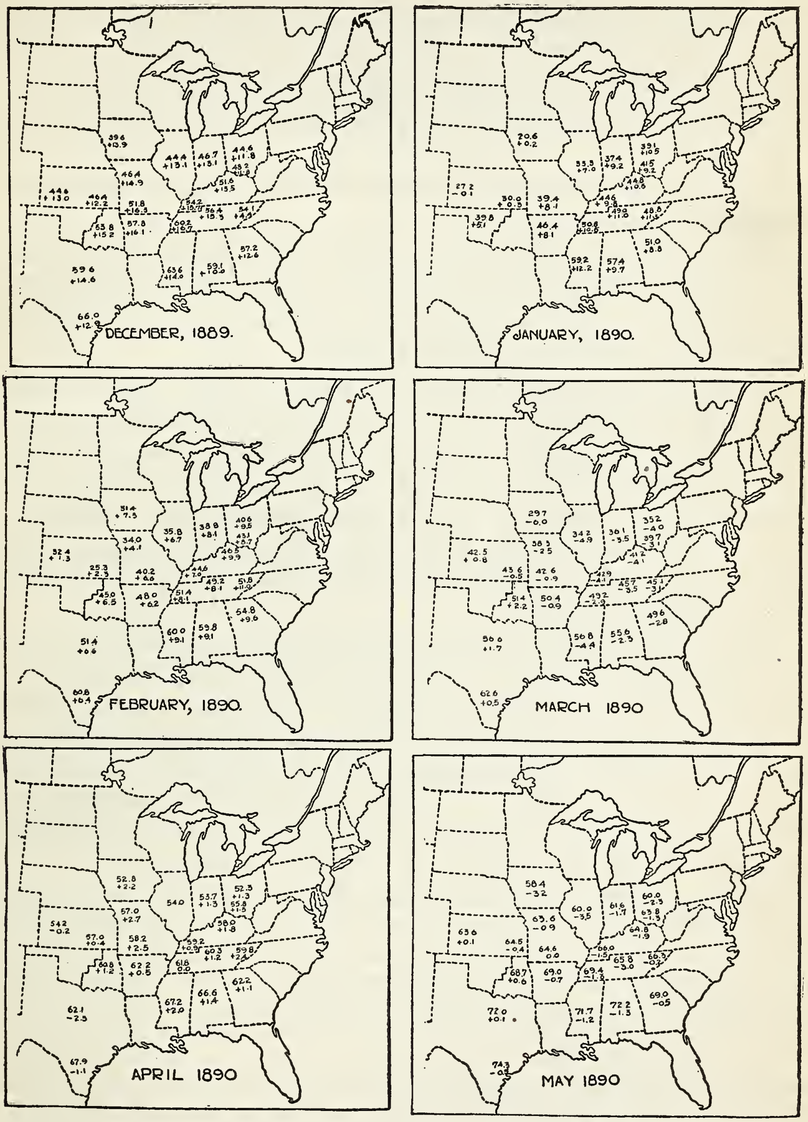

Diagram II.—Maps of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below normal), for the critical period December, 1889, to May, 1890; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

the observations being made June 10, 1890. In Missouri the situation appears to have been pretty clearly set forth by Colman's Rural World, then the leading agricultural paper of the Southwest. In the

issue of that publication for June 12, 1890, the following statement is made:

The oat crop in the vicinity of St. Louis and probably extending a hundred miles in every direction is being completely destroyed this season by an aphis, commonly called, we believe, the Texas louse. The oat fields look brown and bare, this little green insect sucking the juices and sapping the vitality of the plant. It increases with amazing rapidity, fully as rapidly, we judge, as the hop louse, swarming in every direction and carrying destruction in its path. The only thing they seem to feed upon is the oat.

In the issue of the same publication for June 19, a week later, the following statement is made:

The oat crop this season will be almost a total failure in St. Louis County. Hundreds of acres have been totally destroyed by the aphis, or plant louse, the depredations of which have been so widespread and effective that only a very small per cent of the crop will mature. Hundreds of farmers have despaired of the crop entirely, and have plowed up their oat fields and planted corn instead.

The Weather Crop Bulletin of the Missouri State Board of Agriculture for the week ending July 4, 1890, gives the following estimates of the oats crop throughout the State. Northeastern Missouri, 63 per cent; northwestern Missouri, 70 per cent; southeastern Missouri, 25 per cent; central Missouri, 30 per cent; southwestern Missouri, 54 per cent. As another writer describes it, the damage was most serious south of a line drawn diagonally across the State from the northeast to the southwest corner.

The statement made in Colman's Rural World to the effect that the oats crop within a radius of a hundred miles of St. Louis had been completely destroyed by the oats aphis or "Texas louse" would include within this radius territory nearly half way across southern Illinois. Mr. B. F. Johnson, of Champaign, Ill., an agricultural writer, who appears to have traveled over the country quite extensively and observed the situation closely, writing to the Country Gentleman under date of June 24, sized up the situation as follows:

For some weeks after it was seen above ground, the oat crop looked well and promised well, and this continued to the first or about that date in June. Since then oats have been going behind hand, with the threat now over them that all the crop has been more or less seriously reduced in yield and a considerable portion will be lost. In fact, the oat aphis, after ruining the oat crop south, has appeared on the black soil in force and nothing less than many and heavy rains will arrest his progress. As before reported, the dry weather in May favored a light growth of straw, as in 1887, and hopes were entertained that long heads of sound grain would result. Such would have been the case had not the aphis appeared and sucked a part of the life-blood of the plants. The present appearance of a majority of oat fields—the acreage on the black soil counties is an enormous one—is rather uneven as to growth, color, and measure of development, a part of which is owing to the greater or less fertility of the soil, but chiefly to the depredations of the aphis, that takes the weakest plants growing on the thinnest land.

In the issue of August 14 of the same publication, Mr. John M. Stahl, of Adams County, Ill., states that in western Illinois the only

cause of the failure of the oats crop recognized was the green louse. Directly upon this point his statements were as follows:

We never had a better prospect for oats until the green louse began its work. Some fields were not attacked by the louse, though it infested surrounding fields. From the fields not attacked by it there was a splendid yield of oats; while, of course, the other fields yield scarcely anything. In every township there were a few fields that were not attacked by the green louse and that made a good yield. The fact that those fields not attacked by the green louse invariably made a good yield, while those that were attacked made a poor yield, is proof that in this part of the State, at least, the green louse was the prime cause of the failure.

This feature of the apparent immunity of some fields from attack while others adjacent were destroyed has since been observed again and again, especially along the borders of a serious invasion, which was precisely the stuation in western Illinois at the time indicated by Mr. Stahl. In Indiana the senior author investigated the outbreak personally, and while the pest was present as far north as Lafayette, there was little if any damage from its attacks north of Indianapolis. In the neighborhood of Franklin on June 25 many fields were badly damaged, but the injury was much more severe to the southward and at New Harmony, Ind., on June 11, the oats crop was ruined. The same was to be said of the country across the Wabash River in Illinois. While both Toxoptera and Siphonophora were present in most cases the former largely outnumbered the latter and there was no difficulty in properly crediting the destruction to Toxoptera.

The occurrence of this insect in southern Ohio was greatly obscured owing to the fact that it was, as elsewhere, confused with *Macrosiphum granaria* Buct. Clarence M. Weed, writing for the Ohio Farmer (see issue of July 12, 1890), states that in Ohio the grain plant louse had been reported from Pickaway, Clermont, Butler, and Franklin counties. It seems, however, that in Clermont County, according to Mr. Ed. C. Ely, the plant lice were at work as early as May 30.

In a later issue of the same paper, July 19, 1890, Hon. Abner L. Frazer, of Clermont County, Ohio, stated that the aphidids were very numerous in his fields on June 9. While it is impossible to say with absolute certainty that all damage was due to Toxoptera, nevertheless Waldo F. Brown, writing from Butler County[1] on June 19, says:

Oats are in a critical condition. The leaves have turned red. It has not the appearance of rust, looking more like the firing of a plant in dry weather, and I should not wonder if the crop proved a total failure.

In both Illinois and Missouri the aphidid causing the damage was termed the "Texas louse," and wherever a technical name for it was used at all it was called *Siphonophora avenæ* Fabr. Because Toxoptera was at that time but little known, and owing to the

[1] Country Gentleman, June 26, 1890, p. 506.

extreme difficulty in separating its young and its wingless adults from those of other species, it would seem that more or less damage to the oats crop might be with justice accredited to Toxoptera in Butler, Miami, and Clermont counties in extreme southern Ohio.

THE OUTBREAK OF 1901.

(Fig. 5, p. 20; Diagram III, p. 25.)

The outbreak of 1901 was less extensive than that of 1890. Little damage was reported south of Waco, Tex., but from this point northward wheat was more or less injured, and oats were destroyed to the northward into what was at that time Oklahoma and Indian Territories. The farthest point to northeast at which damage was reported, with specimens of the depredator, was Saratoga, in extreme southwestern Missouri. The specimens accompanying correspondence from Texas and Oklahoma gave ample proof of the identity of the destroyer, which in Texas alone ruined grain to the extent of several million dollars. In central Texas the ravages of the pest began to attract attention early in March, while the report from Missouri came under date of April 30. It will be noticed that the direction taken by this invasion followed very closely that of 1890 (see fig. 5), beginning, however, farther south in Texas, not extending so far to the northeast, and dying out, as it were, earlier in the season. These phenomena will be explained farther on under meteorological influences.

THE OUTBREAK OF 1903.

(Fig. 5, p. 20; Diagram IV, p. 26.)

As foreshadowing the impending outbreak of 1903, as early as November 26, 1902, Mr. J. F. Ordman, writing from Windthorst, Tex., complained to this bureau of the ravages of the green louse, stating that it had destroyed several small areas in his wheat field and that it was reported generally prevalent in his neighborhood. This outbreak was, however, an incipient one and resulted in little injury, the seriously infested areas being confined to northern Texas, exclusive of the "Panhandle," with possibly the country in the then Oklahoma and Indian Territories bordering the Red River, and in South Carolina. While the outbreak was thus limited in area, the natural enemies of the pest in the West evidently fell far short of completely subjugating it. In March, 1904, Prof. E. D. Sanderson and Mr. E. C. Sanborn found it in Grayson County, Tex., sufficiently abundant to work serious injury in the fields of young wheat and oats, in some cases the destruction of the growing grain

being complete. The same gentlemen reported the pest present in limited numbers during the spring of 1904 in Collin, Hunt, and

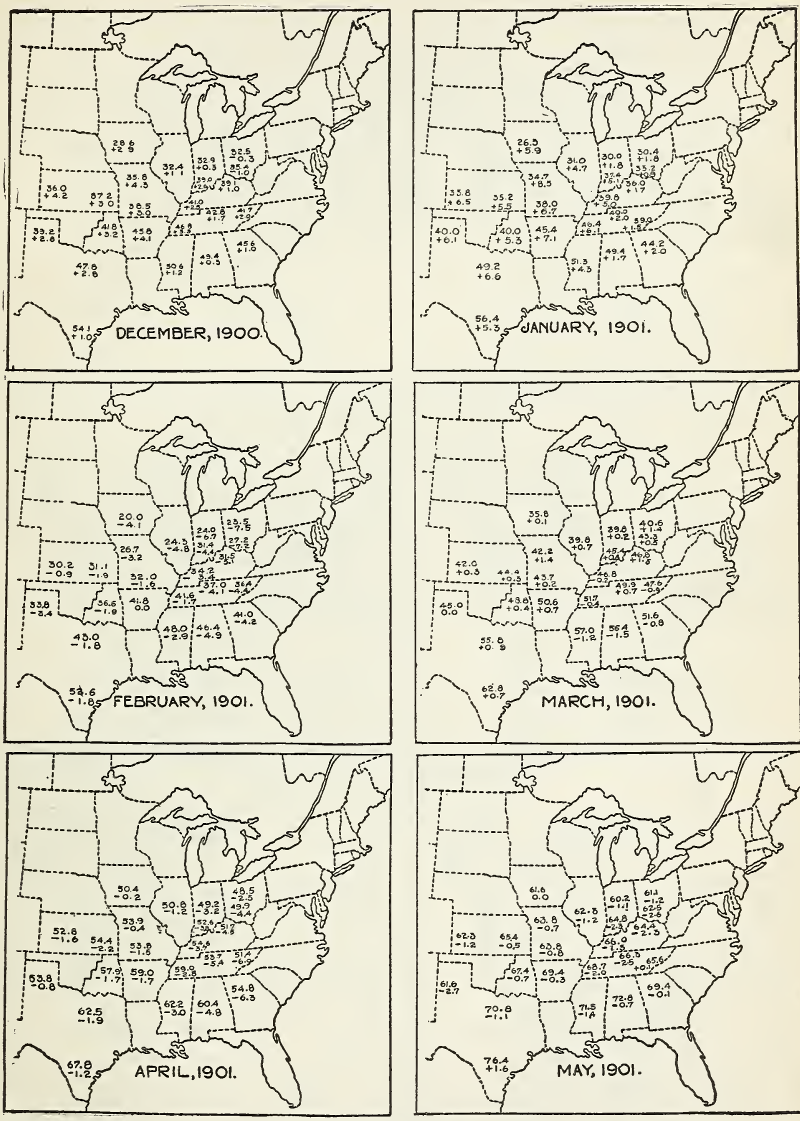

Diagram III.—Map of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below), for the critical period December, 1900, to May, 1901; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

Travis counties. This year, however, the parasites evidently did more effective service, as at Whitewright, Grayson County, Tex., on March 10, 1904, Mr. Sanborn found that 60 per cent of the Toxoptera

in some oats fields were parasitized. The junior author spent some time in northern Texas during November and December, 1904,

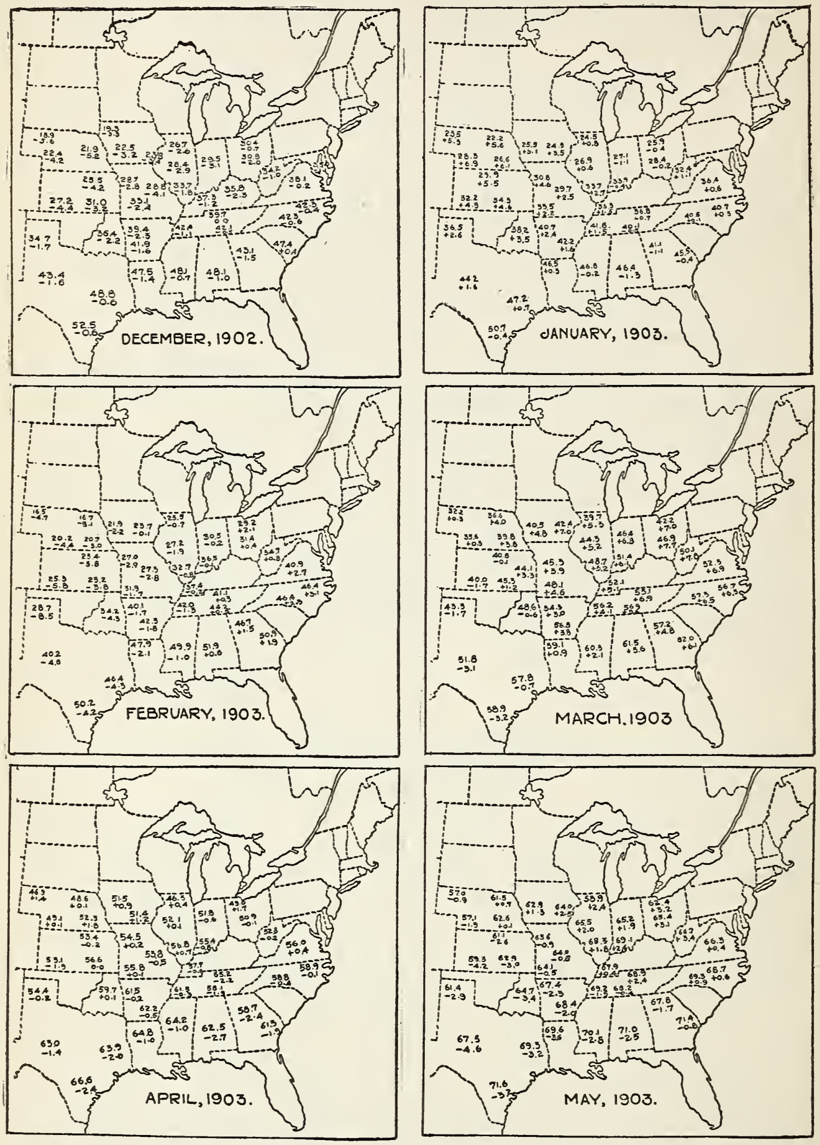

DIAGRAM IV.—Map of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below), for the critical period December, 1902, to May, 1903; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

investigating insects in the fields of wheat and oats without finding the pest. He was not looking for this species particularly, and it was doubtless still present in very limited numbers.

THE OUTBREAK OF 1907.

(Fig. 5, p. 20; Diagram V, p. 28.)

The outbreak of 1907 was by far the most serious and widespread that has occurred in the United States up to the present time. Starting in east-central Texas, the invasion swept northward and eastward, covering a somewhat fan-shaped area, through Oklahoma, Kansas, northwestern Arkansas, Missouri, and across Illinois to within 60 miles of Chicago. Though possibly not doing so much damage in the Ohio Valley as in 1890, it extended westward through Oklahoma and Kansas into southeastern Colorado. While not especially injurious to oats and not at all to wheat in the States of Nebraska, Iowa, Minnesota or the Dakotas, the late Dr. James Fletcher states that in Canada it actually did some damage in Saskatchewan. Less damage was probably done in Indiana and Ohio than in 1890, though the ravaged area in general followed the ground covered by the previous outbreaks; in this latter case the northeastern terminus of the seriously ravaged area appeared to be confined more closely to the upper Mississippi River and Illinois River valleys than to that of the Ohio River, thus sweeping more broadly to the northward. On the Atlantic coast fall oats were destroyed or badly injured in South Carolina, and both wheat and oats in western North Carolina. In Virginia, Kentucky, and Tennessee neither grain was, as a rule, seriously damaged. The areas shown in figure 5 indicate all injury, even though slight, in occasional and widely separated fields. In the valleys of the upper Missouri River and the Red River of the North there was little or no injury, and it seems doubtful if the pest occurred in that section prior to this outbreak.

Forebodings of trouble from this pest came as early as November and December, 1906. According to copies of Mr. Sanborn's notes, as placed at our disposal by Prof. A. F. Conradi, the species was sent to the Texas experiment station from Howe, Grayson County, Tex., where it occurred on oats, as early as November 14, 1906, and one day earlier from Allen, Collin County, of the same State, where it was present in great numbers attacking volunteer oats plants. On December 22, 1906, it was sufficiently abundant about Plano, Collin County, Tex., to destroy oats in patches in the fields, its natural enemies at the time being in a dormant condition because the temperature had not reached and remained at a degree that would render them active. During January and February, 1907, these conditions continued, the Toxoptera breeding and spreading unrestrained by its enemies, so that the area over which it was becoming destructive continually increased.

Rumors of injuries by this pest came to us early in January, 1907, from east-central Texas, where the "green bugs" were reported to Mr. W. D. Hunter, in charge of cotton boll weevil investigations of

this bureau, as attacking fall oats. During this month in Texas east of a line drawn from near Gainesville through Abilene and San

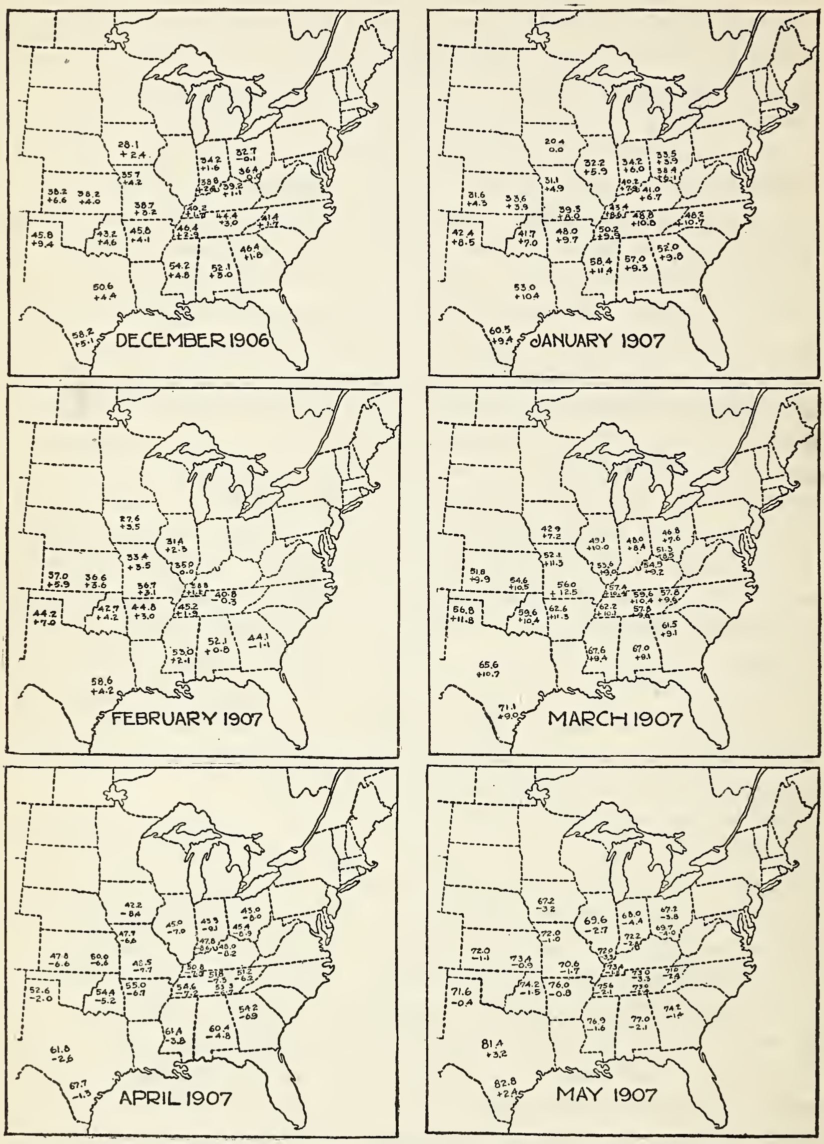

DIAGRAM V.—Map of the United States east of the Rocky Mountains, showing normal temperature, upper line, and departure therefrom, lower line (+, above normal, and −, below), for the critical period December, 1906, to May, 1907; above normal (+) in winter and below normal (−) in spring being favorable for outbreak of spring grain-aphis. (Original.)

Antonio to Galveston the temperature was 9° F., above the normal. Within this area was a smaller one, the boundaries of which may be indicated by a line drawn from Texarkana to Fort Worth, Waco, and

Joaquin. Over this latter area the temperature for the same month was 12° F. above the normal, and within this latter area the pest first began its work of destruction.

For reasons to be explained later in their proper place, the spread of the pest was much more rapid to the north and northeast from north-central Texas than it was in the opposite direction. In March the pest was found generally present about San Antonio, Kerrville, Menardville, and New Braunfels, of that State, but because of the small acreage of grain grown in that section the damage was not serious. Indeed, the same may be said of the country west of a line drawn from western Wilbarger County to the Brazos River at Round Timber, Baylor County, and west of the Brazos to and except about Waco. East and north of this the damage ranged from serious to total ruin.

As early as March 6 it was also reported to the bureau as destroying wheat in the vicinity of Summers, northwestern Arkansas. This was probably due to local causes, uninfluenced by invasions of swarms of winged viviparous females that were being continually swept from off the more disastrously affected country to the southwest and drifting toward the northeast. Mr. C. N. Ainslie was instructed to proceed from Washington, D. C., to this part of the country, where he arrived on March 16. On March 15 the Texas Grain Dealers' Association, through its secretary, Mr. H. B. Dorsey, made an appeal to the chief of this bureau for aid in devising means for destroying the pest and curtailing or preventing its ravages. In response to this appeal the junior author was dispatched to Fort Worth, Tex., arriving there on March 26. The situation here was found to be most serious. Hundreds of acres of both wheat and oats had been wiped out of existence; in many cases fields were observed where it was impossible to find a living plant, and as a rule numbers of such fields were being plowed and prepared for other crops. Plate I, figure 1, shows a field entirely destroyed. The weather at this time was hot and dry and Toxoptera appeared to have been entirely overcome by its natural enemies.

On March 25, 1907, a telegram was received from the Roosevelt Grain Elevator Co., of Hobart, Okla., reporting serious attacks from Toxoptera and appealing to the Secretary of Agriculture for assistance. The junior author was at once instructed to proceed to Hobart, where he arrived April 1, remaining until April 5. This point appeared to be on the western border of serious injuries by the pest, and the situation was therefore not so grave as in Texas. From the junior author's observations it appeared that much of the damage that was being done was caused by insects which had drifted into the fields and not from individuals originating therein. This was evidenced by the fact that in wheat fields where a part had been sown

early and the remainder later in the season the latest sown was very much more seriously damaged than that sown earlier. About the only portions of the early-sown part of the field to suffer serious injury were on the poorest soil. In short, the Toxoptera was found to be working its greatest damage in late sown or pastured wheat fields and among the young oats. Natural enemies were busily at work and apparently fast overcoming the pest.

In the meantime Mr. Ainslie had found the pest destroying wheat in spots in the wheat fields about Fayetteville and Summers, Ark., March 16 to 20, as well as at Chandler, Okla., March 24, and at Guthrie, Okla., on March 25. Near the latter place large circles were observed in the otherwise green fields of wheat. In the center of these circles the red soil was exposed by reason of the killing of the wheat plants, and these exposed circular areas were bordered by a band or girdle of yellow half-dead wheat plants, where the Toxoptera were most abundant. (See Pl. I, fig. 2.) In another field in this vicinity there was a stack of oats straw of the previous year, and from this stack a dead area extended at least 100 feet to the south. This area was nearly circular, with the stack almost in the center of the circumference. Near and surrounding the stack was an area of dead volunteer oats, and beyond this a stretch of bare ground indicated where wheat had once stood. From people occupying a house near by something was learned of the previous history of this straw stack from which Mr. Ainslie determined that volunteer oats had sprung up after thrashing in 1906; these oats turned brown soon after, causing some wonder among farmers, and during the winter the plants died. The trouble spread to the wheat adjoining and here the wheat plants died early in the spring. There was here seemingly a repetition of the conditions in the fields about Summers, Ark., where Toxoptera infesting volunteer oats extended its destruction from these to the wheat near by.

On March 26, between Guthrie and Kingfisher, Okla., Mr. Ainslie observed that the dead spots in the wheat fields were a striking feature of the landscape, for in the sunshine the bright green of the young grain made a striking contrast with the yellow-rimmed red circles where the Toxoptera had destroyed the wheat. Occasionally a field was free from these areas, but more of them were frightfully spotted in this manner. A field of wheat that was pastured more closely than most grain fields lay in the edge of Kingfisher and showed the attack of the Toxoptera worse than in adjoining grain. On March 27, at Kingfisher, Toxoptera was flying by the millions, the air being full of the migrants, and farmers who drove to town were covered on the windward side to their annoyance. The aphides seemed for the most part to fly low, but the wind hurried them at such a rapid rate that they might easily have been invisible when higher in the air. On the

following day large numbers of Toxoptera were on the wing, always moving north. In a field of oats, sown in February, the plants had hitherto been very thrifty, but at this time in a great many of the drill rows the plants were about dead for a space of 8 or 10 feet, and in case of later sown fields the plants were all fast dying under the attack. There was becoming gradually apparent a fact of considerable importance regarding the relative number of winged forms in the fields. In oats fields where the food was succulent and good it was difficult to find a single pupa, while in older and less succulent wheat, perhaps within a yard of the oats, pupæ would form 75 or 80 per cent of the population of the blades. This was afterwards verified repeatedly by observation and by actual counting; indeed, throughout the entire spring this fact seemed to be substantiated.

From March 31 to April 3 Mr. Ainslie carefully examined fields of wheat and oats in the vicinity of Wellington, Kans. He found wheat fields invariably evenly infested with Toxoptera though nowhere in any great numbers. Many of these were winged adults, indicating that they were migrants, and the young about them clearly evidenced a recent invasion. No dead areas were observed in the fields north of Pond Creek, Okla., but between Kingfisher and this point the circular dead spots were plainly in evidence. These dead areas, (Pl. I, fig. 2), from their regularity in the field, plainly indicated the rows of oats shocks of the fall previous and were clearly to be seen where the oats had been shocked and allowed to stand through a period of wet weather. This generally produced a vigorous growth of volunteer oats when the shocks were finally stacked or removed, and in this young grain the Toxoptera seem to have had an early start. In some cases it was easily possible to observe these spots all over a field, although the volunteer oats were rarely entirely killed—perhaps only changed to a reddish color. The infestation seemed to be more marked in the wheat in the vicinity of these spots, and later the Toxoptera swarmed about these places.

It may be noted that these observations of Mr. Ainslie in northwestern Arkansas, southern Kansas, and northern Oklahoma were made upon the same dates as those of the junior author about Fort Worth, Tex., and at Hobart in southern Oklahoma, thus covering a latitude of nearly 400 miles.

Mr. Ainslie returned to Kingfisher, Okla., April 3, and was joined there by the junior author on the 8th of the same month, where a number of experiments were carried out in the field, the results of which are given in the proper place. By the 8th of the month parasitized Toxoptera was found excessively abundant in the fields, in evidence of which a case was noted where a section of a leaf of wheat 1½ inches in length carried 43 brown, parasitized individuals. Mr. Ainslie left Kingfisher, Okla., for Wellington, Kans., on the following

day, taking with him more than a bushel of these wheat plants with the parasitized Toxoptera thereon and on the 11th this material was put out in a field near Wellington where the Toxoptera was the most plentiful, in order to determine if it was possible to increase the limited numbers of parasites at the time observable in the field, so as to expedite the work of the latter in overcoming the pest. This was the first artificial introduction of Aphidius into Kansas, six days after which Prof. S. J. Hunter began distributing parasites. The following day a second lot of material sent from Kingfisher by the junior author, some of it carrying as many as 100 parasitized Toxoptera to a single blade of wheat, was distributed in a wheat field, also near Wellington, by Mr. Ainslie, some of it being placed in bunches to protect it from the weather and the remainder scattered over the ground among the growing wheat. The Aphidius already observed in the fields on the 11th appeared to be on the increase, as many as 11 parasitized individuals being observed on a single growing leaf, though but few of the adult parasites were observed abroad in the fields. On April 18 parasites were sent to McPherson and on May 18 to Manhattan, Aphidius being present in the fields at the time of introduction. These introductions will be taken up in detail farther on in this bulletin.

On April 12 a letter was received from Mr. J. A. Akers, at Hooker, Beaver County, Okla., stating that the "green bug" was destroying his wheat. The junior author, being notified of the outbreak, proceeded there, arriving on April 24, and found that Mr. Akers's field was the only one in that locality that had been injured, and, in fact, it was outside the zone of destructive infestation in this State. This field comprised 52 acres, over a portion of which oats had been sown the previous year, while cowpeas had been grown upon another and much smaller part. Volunteer oats were plentiful over the first mentioned area. One of the infested spots was located among the wheat and volunteer oats, while the second spot was in the area previously devoted to cowpeas. There were no other injured spots in the whole field, although an occasional Toxoptera could be found here and there over the field, which was also true of other fields in this vicinity. It is a significant fact that young plants of *Agropyron occidentale* Scrib. were found growing in both of these spots and they were as badly infested as the wheat plants. A few parasitized Toxoptera were found, but the parasites were apparently developing slowly on account of cold weather.

The junior author went to Indiana the latter part of the first week in May, but was recalled to Kansas and reached Manhattan on the 18th, where he was met by the senior author, and a final experiment for the artificial introduction of parasites was here planned and begun at this time, the results of which are given farther on in the proper place.

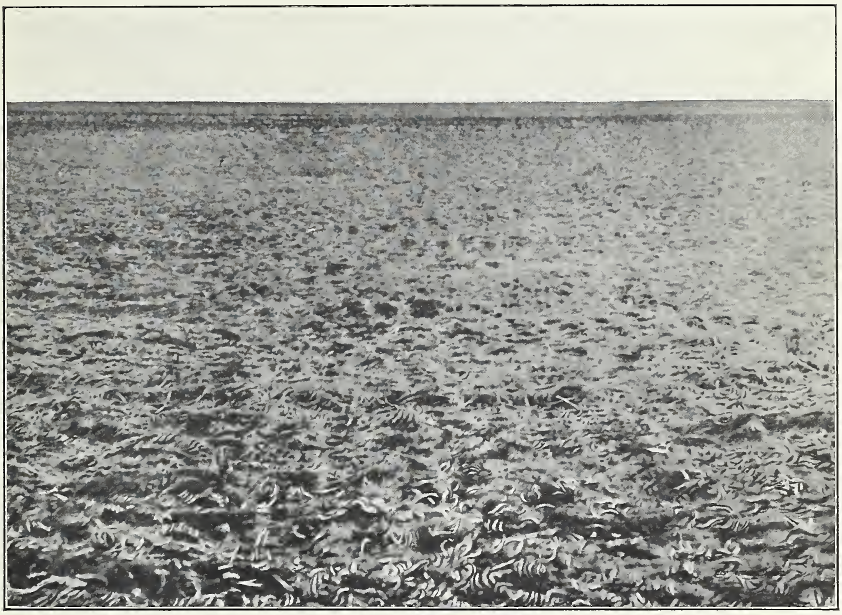

FIG. 1.—WHEAT FIELD TOTALLY DESTROYED BY THE SPRING GRAIN-APHIS (TOXOPTERA GRAMINUM).

Contrast with uninjured portion of field shown in figure 2. (Original.)

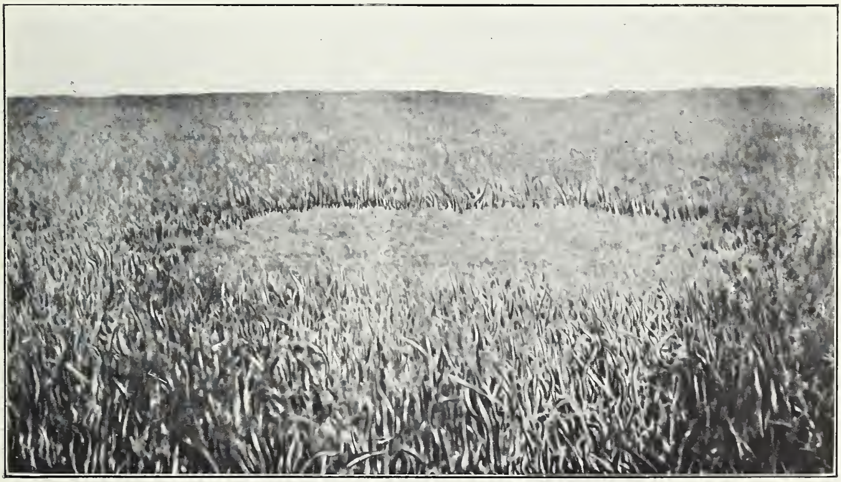

FIG. 2.—CIRCULAR SPOT IN WHEAT FIELD WHERE GROWING GRAIN HAS BEEN DESTROYED BY THE SPRING GRAIN-APHIS.

The growing grain on these circular areas is as completely destroyed as in the field shown in figure 1. Increasing in size and number, the spots come to include whole fields. (Original.)

From here the junior author made a trip into northwestern and northeastern Kansas and south-central Nebraska to determine the northern limit of destructive infestation. The following places were visited: Solomon, Dickinson County, Kans.; Beloit, Mitchell County, Kans.; Lenora, Norton County, Kans.; and Kearney, Buffalo County, Nebr. The infestation at all of these places was very slight and no damage was done. At two places only, Solomon and Beloit, were parasites found.

The senior author in the meantime proceeded to Great Bend, Barton County; Dodge City, Ford County; Garden City, Finney County; and Syracuse, Hamilton County—all in Kansas. The object of this trip was to see how far Toxoptera had spread to the westward. It was found at all of the above points, doing considerable injury; at Syracuse an unirrigated field of oats of 10 acres was found bordering an irrigation ditch. Along this ditch was a ragged border from 10 to 30 or 40 feet in width of vigorously growing oats where the "green bug" had apparently done no injury, while beyond this border, where the moisture from the ditch had not penetrated, the loss was total. In another case in the same locality, a part of the wheat in an unirrigated field came up in the fall and the rest not until the following spring; the former was uninjured by "green bugs," while the latter was killed. From Syracuse the senior author proceeded to Wellington, Kans., to join Mr. Ainslie.

In a letter dated June 5, 1907, Prof. C. P. Gillette states that he made a trip into the Arkansas valley early in the spring and found Toxoptera doing very serious injury to wheat fields; to such an extent was this the case that he advised some of the farmers to plow up some of their fields and plant other crops. Following this trip there was a heavy snowstorm and the "green bugs" were greatly diminished in numbers, though at the date of his writing (June 5) Toxoptera was abundant in the fields.

On July 9 Prof. Gillette sent us badly parasitized Toxoptera on blue grass from Fort Collins, Colo., with the statement that the "green bug" had largely disappeared from the grain fields in that locality.

Mr. Ainslie remained in the vicinity of Wellington, Kans., from the last week of April to the 21st of May, at which date he was joined by the senior author and went south to Kingfisher, Okla. The conditions found there were serious in the extreme, most of the grain fields being bare and many had been plowed and displaced by other crops. Between Wellington, Kans., and Kingfisher, Okla., a strip of country was encountered by them about 30 miles in width, beginning above Medford, Okla., with Pond Creek about midway between, and extending almost to Kremlin, Okla., over which the injury from Toxoptera was not nearly so great as in the country both to the

north and south. This area was investigated by Mr. Ainslie on the 23d of May. There was plenty of evidence of Toxoptera attack. Some fields were killed outright and others badly spotted, but a number of fields were little injured. No particular reason could be assigned for this condition of the fields, and this area, with a few interruptions, extended on to the west indefinitely. This belt extending across the wheat-growing section of Oklahoma was evidently observed by Mr. Sanborn, who stated in his notes, copies of which were furnished by Prof. Conradi, under date of March 29, 1907, "Northern boundary of parasitized infestation is between Kingfisher and Enid." Again, under date of March 30, "Pondcreek, Okla. Doing great damage, in large spots, here. There lies a peculiar feature between this and Kingfisher. At these two points the infestation was about equal. Enid has no damage yet."

Mr. Ainslie now started northward to trace Toxoptera to its most northerly point in the United States and to learn to what extent its parasite occurred with it, stopping at the following places: Kingman, Kingman County, Kans.; Hutchinson, Reno County, Kans.; Sterling, Rice County, Kans.; Scott, Scott County, Kans.; Great Bend, Barton County, Kans.; Oakley, Logan County, Kans.; Colby, Thomas County, Kans.; Goodland, Sherman County, Kans.; Manhattan, Riley County, Kans.; Lincoln, Lancaster County, Nebr.; Plainview, Pierce County, Nebr.; Dixon, Dixon County, Nebr.; Sheldon, O'Brien County, Iowa; Mason City, Cerro Gordo County, Iowa; Dodge Center, Dodge County, Minn.; Rochester, Olmsted County, Minn.; Brookings, Brookings County, S. Dak.; Aberdeen, Brown County, S. Dak.; Fargo, Cass County, N. Dak.; East Grand Forks, Polk County, Minn.; Hallock, Kitson County, Minn.; Grafton and Park River, Walsh County, N. Dak.; Larimore, Grand Forks County, N. Dak.; and Casselton, Cass County, N. Dak. He reached the last-mentioned place on August 5, after which he returned to Washington, D. C.

Except at Kingman, Hutchinson, Sterling, Great Bend, and Manhattan, Kans., Mr. Ainslie found but little damage resulting from Toxoptera, the most striking feature being the fact that parasites were found associated with Toxoptera at each point visited with the following exceptions: Goodland, Kans., very few Toxoptera in this immediate vicinity; Lincoln, Nebr., no Toxoptera found; Brookings, S. Dak., 2 to 3 Toxoptera only seen; Aberdeen, S. Dak., no Toxoptera found; Fergus Falls, Minn., only 1 Toxoptera observed here. The significant feature of this is that no parasites were introduced artificially at any of these points outside of Kansas.

From statements made by Prof. J. M. Stedman, who was professor of entomology at the University of Missouri at this time, it appears that Toxoptera was swept over the border from Oklahoma and Kansas into southwestern Missouri. Prof. Stedman states that there were from six to eight counties in the southwestern corner that were very

badly infested; outside of these counties the infestation was slight. He received very few if any reports of its occurrence north of the Missouri River. It probably occurred in the northern part of the State also, as the bureau received a report, with specimens, of injury to oats at Weaver, Lee County, Iowa, and Mr. C. N. Ainslie found it occurring in small numbers at several points in northwestern Iowa.

From reports received by this bureau it seems that Toxoptera was very abundant in northern Illinois, confining its injuries chiefly to oats. Mr. Edgar McGee, of Sciota, McDonough County, Ill., sent us specimens July 5 which proved to be Toxoptera, and in a letter dated July 29 he stated that it was very widespread, that his and adjoining counties were badly infested, and that some fields of oats were so seriously injured that the owners had plowed them under and planted other crops. The yield in that locality, from Mr. McGee's report, seems to have been greatly reduced.

At Sandwich, Dekalb County, Ill., there was apparently considerable damage to oats; no specimens were received; the injury in all probability was, however, due to Toxoptera. To quote from a letter from Mr. Clark Graves, bearing date of July 12:

> I have today mailed to you, under separate cover, a fair sample of the oats of this vicinity, and I think from general appearances that the crop will be shortened half on account of the green bug. The bugs have now disappeared, and it would seem that the late oats have suffered considerably more than the early ones.

There were no specimens of plant-lice in this material from Mr. Graves.

A report, with specimens, was received from Manteno, Kankakee County, Ill., which stated that that section had suffered considerably from "green-bug" attack.

We have only one record of serious injury from Indiana in 1907 that can without doubt be attributed to Toxoptera. This was in a small field of oats just outside the limits of Indianapolis. The junior author examined this field and found that over an acre had been seriously affected, part of it being entirely destroyed. The "green bug" disappeared from the oats before the latter headed out, probably overcome by Aphidius and other enemies. This infestation apparently originated from rank bluegrass growing along one side of the field. Later in the season, when the oats had been harvested, Toxoptera could be found along this margin on the bluegrass, where the sexes appeared and eggs were produced. Toxoptera was found at other points in Indiana, but only in small numbers.

Mr. T. H. Parks, of this bureau, states that in the latter part of June, 1907, the oats on his father's farm in Pickaway County, Ohio, were badly damaged by aphides. He states that parts of some fields in the neighborhood were scarcely worth cutting. Aphides were very abundant on the plants and parasitized aphides were very plentiful also. The oats plants that were badly infested turned brown, and

before they were ready to head out the aphidids disappeared. This was probably due to the presence of the parasites. Wheat was not attacked or injured by these aphides. Mr. Parks did not have any of this material identified, and we can not say absolutely that this was *Toxoptera graminum* Rond., but the character of the attack, the sudden disappearance of the aphidids, and the fact that they did not disturb wheat coincide with our observations on this insect in this latitude and to us clearly point to Toxoptera as the originator of the trouble.

Part of the trouble referred to in letters cited in Bulletin 210 of the Ohio Agricultural Experiment Station was, in all probability, due to "green-bug" attack, since from our own observations on this species in northern latitudes a part of this injury appears to be characteristic of Toxoptera.

North and South Carolina also suffered somewhat from the depredations of this insect in 1907. The senior author made a trip into this section, reaching Sumter, S. C., April 17, 1907. He found that all fields of oats, the only grain sown, were more or less affected; here and there brown areas occurred, showing the characteristic work of Toxoptera. This condition was noticeable from Sumter, S. C., to Charlotte, N. C., indicating that the infestation was general. Both *Macrosiphum granaria* Buckt. and *Toxoptera graminum* Rond. were present, but the latter was by far the more numerous. There were very few parasites or coccinellids in evidence. In a letter dated June 18 Mr. E. C. Haynsworth, of Sumter, stated that soon after the senior author's visit in April the weather became warmer and Toxoptera disappeared very rapidly.

In some parts of North Carolina the injury was quite serious. Mr. Franklin Sherman, jr., of the North Carolina Department of Agriculture, has kindly placed his notes on this outbreak at our disposal. He stated that the worst area of infestation centered about Winston-Salem, in Forsyth County, N. C., although some injury was also inflicted in Guilford, Davie, and Rowan counties in the same State, some fields being almost totally destroyed. Parasites were present, though not in sufficient numbers to hold Toxoptera in check.

The senior author went directly from Sumter, S. C., to Winston-Salem, N. C., reaching the latter place April 19, where he was met by Mr. Sherman, and they went over the ground together. A number of fields were examined, ranging from slightly infested to totally destroyed. In some fields of wheat, where there had been quantities of volunteer oats, the infestation was more severe. Parasites were present in great abundance in some fields, but they did not appear to have checked the pest in time to save all of the fields.

The senior author thus summarizes this outbreak:

From a study of the entire neighborhood it seems quite evident that the outbreak of Toxoptera in the vicinity of Winston-Salem was primarily due to the presence of

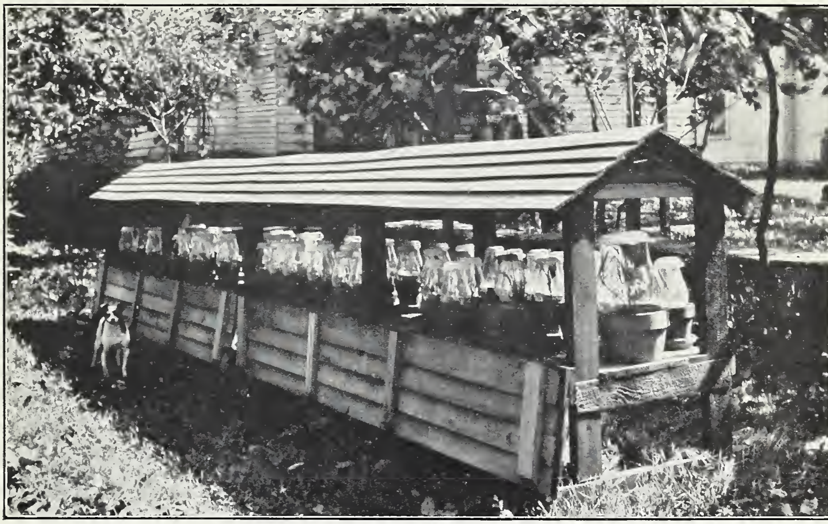

FIG. 1.—STAND ON WHICH REARING EXPERIMENTS WERE CARRIED OUT IN REARING THE SPRING GRAIN-APHIS. (ORIGINAL.)

FIG. 2.—AREA ON GROUNDS OF THE UNITED STATES DEPARTMENT OF AGRICULTURE, AT WASHINGTON, D. C., WHERE THE SPRING GRAIN-APHIS USUALLY OCCURS ON BLUEGRASS IN EXCESSIVE ABUNDANCE DURING SUMMER.

The area infested is indicated by a +. (Original.)

fields of fall oats and more or less volunteer grain in other fields, all of which constituted breeding grounds for the pest during the preceding autumn, and from which winged individuals migrated and established new colonies in other fields; these, owing to influence of weather on the development of parasites, caused the most of the injury in wheat.

We received a letter with specimens from Mr. L. M. Smith, Mr. Sherman's assistant, at Newport, Carteret County, N. C., stating that he found a small field of oats in the outskirts of town that was considerably damaged by Toxoptera. This county is on the coast and Newport has an elevation of 19 feet. From this it seems that in all probability Toxoptera covered the entire State.

The senior author also found Toxoptera in destructive abundance at Midlothian, Chesterfield County, Va., in a small meadow of orchard grass. Mr. J. L. Phillips, the State entomologist, reported a slight outbreak at Cloverdale, Botetourt County, Va., in rye, and stated that considerable damage had been done in some parts of the field. One undetermined Aphidius was found at Midlothian, while none was reported from Cloverdale.

There was an outbreak of Toxoptera in the bluegrass lawns north of the buildings of the Department of Agriculture at Washington, D. C., in July, 1907. The infested area (see Pl. II, fig. 2) was apparently confined to the space of about an acre, where it was excessively abundant; outside of this area practically no Toxoptera could be found. This offered a good opportunity to test spray materials and a number of experiments of this kind were carried on.

Dr. Howard, personally, found Aphidius present in this infested area though in very limited numbers. In all probability this was *Aphidius avenaphis* Fitch, as we have since found this species in this exact locality but at no time have we found *A. testaceipes* Cress., which, until Mr. Viereck revised this group, had been considered to be *Lysiphlebus tritici* Ashm. We did not, in 1907, find any species of Aphidius present and did not know that Dr. Howard had done so, as he soon after sailed for Europe and at the time Circular 93 of this bureau was published the statement as to its nonoccurrence was not called to his attention in time to be corrected and he did not inform us of his find, supposing that we knew of it already. Mr. Kelly, however, found *Allotria* sp. present there in 1907, and we have since found this to be a parasite of Aphidius, which may account for the fact that the latter was present in such limited numbers. In 1908 *Aphidius avenaphis* was quite plentiful there, although specimens were not preserved, while *Allotria* sp. was found sparingly on the grounds elsewhere in the vicinity. As Toxoptera attracted no attention in this area on the grounds of the Department of Agriculture in 1909 we have no records for that year. In 1910 Toxoptera was again injuriously abundant on the same area and no Aphidius could be found, while *Allotria* sp. was still in evidence. It seems possible that condi-

tions were unfavorable for the rapid increase of Allotria in 1908, which conditions would prove favorable for Aphidius and also unfavorable for its host, the Toxoptera. This infested area on the department grounds in Washington has proved to be of considerable interest, as the fluctuations of Toxoptera there, as well as those of its parasite Aphidius and the secondary parasite Allotria, must coincide with what is going on in similar places over the country, thus forming small secluded breeding areas where Toxoptera survives throughout the summer, more especially in the South. The area in question is a depression covered chiefly by bluegrass, occupying perhaps half an acre, surrounded on all sides except the south by shade trees (See Pl. II, fig. 2.) It is rather more moist and therefore cooler in summer than other portions of the grounds and in common with the rest is kept closely mown. An underground steam pipe which affords heat for a large number of greenhouses extends along the southern and eastern margins; the ground above this pipe is always much warmer than the surrounding area during winter, the snow disappearing first and the grass in that location starting much earlier in spring. So far we have not found that these latter conditions have any influence in enabling the Toxoptera to breed viviparously during the winter. Even when the Toxoptera was excessively abundant here none could be found in the bluegrass-covered grounds only a few yards away, except in 1910, when it was quite numerous about the Washington Monument some four blocks away. Because of its isolation—there are no grain fields within miles on the Maryland side of the Potomac River and the department experiment farm at Arlington, Va., has the only grain for miles on the west side of the river—and because these last had never suffered from Toxoptera attack, this area became of too much importance as a convenient field of observation and experimentation to make an attempt at experimenting with the importation of great numbers of Aphidius desirable. There is every reason for believing that it is in similar favorable localities that Toxoptera passes the summer months in the southwestern portion of the country, where, as observations have shown, it is not able to withstand the high temperatures of the open fields.

Toxoptera has been studied throughout the summer in the Southwest with much difficulty, and not at all satisfactorily for the reason that we have been unable to keep it under continuous observation in the open fields.

Except in cases of local outbreaks here and there over the country there has been no serious injury to grain crops by the "green bug" since 1907. Many additional localities for the species have been added since then, however, and it now appears to cover almost the entire United States, excepting perhaps New York and the New England States. (See fig. 4, p. 19.)

LOSSES FROM DEPREDATIONS IN 1907.

It is impossible to arrive at the actual monetary loss occasioned by this fearful outbreak, as no data have been collected with this special end in view, either by the State or National governments. Several points must be considered in making such an estimate. Large areas planted to wheat and oats were abandoned, part being planted to other crops and the remainder left lying idle. Much money that was entirely lost was expended in seed, fertilizers, preparing the seed bed and planting; of course all of the fertilizer would not be lost where another crop followed. The greatest source of loss came through partial or actual destruction of the young wheat, thus greatly reducing the yield.

The Bureau of Statistics of the Department of Agriculture kindly compiled the following table for us, which will shed some light on the amount of loss probably attributable to the "green bug."

TABLE I.—*Losses from depredations by the spring grain-aphis in 1907 in Kansas, Oklahoma, and Texas.*

	Winter wheat.					Oats.		
	Acreage planted in fall of preceding year (preliminary).	Per cent abandoned.	Acreage harvested (revised).	Yield per acre.	Total production.	Acreage.	Yield per acre.	Total production.
KANSAS.								
				Bush.	*Bushels.*		*Bush.*	*Bushels.*
1905	5,645,000	6.3	5,290,000	13.9	73,527,000	858,000	27.1	23,248,000
1906	5,702,000	10.0	5,132,000	15.3	78,517,000	1,050,000	23.6	24,780,000
1907	5,930,000	4.8	5,645,000	11.3	63,788,000	1,092,000	15.0	16,380,000
1908	5,930,000	2.5	6,108,000	12.8	78,182,000	994,000	22.0	21,868,000
1909	6,173,000	4.5	5,895,000	14.5	85,478,000	964,000	28.2	27,185,000
1910	6,195,000	35.0	4,300,000	14.2	61,060,000	1,400,000	33.3	46,620,000
Average					73,425,000			26,680,000
OKLAHOMA.								
1905:								
Ind. T	286,000	5.5	270,000	10.0	2,703,000	202,000	36.0	7,258,000
Okla	1,493,000	3.9	1,435,000	8.2	11,764,000	294,000	33.0	9,717,000
1906:								
Ind. T	249,000	3.2	241,000	12.0	2,890,000	218,000	34.2	7,447,000
Okla	1,403,000	5.0	1,333,000	14.0	18,664,000	350,000	34.4	12,040,000
1907:								
Ind. T	216,000	28.0						
Okla	1,235,000	35.0	959,000	9.0	8,631,000	418,000	15.0	6,270,000
1908	1,379,000	2.3	1,347,000	11.6	15,625,000	450,000	25.0	11,250,000
1909	1,241,000	6.5	1,225,000	12.8	15,680,000	550,000	29.0	15,950,000
1910	1,604,000	3.0	1,556,000	16.3	25,363,000	632,000	36.5	23,068,000
Average					16,887,000			15,500,000
TEXAS.								
1905	1,319,000	5.3	1,249,000	8.9	11,118,000	914,000	31.4	28,713,000
1906	1,266,000	3.0	1,228,000	11.5	14,126,000	914,000	34.8	31,823,000
1907	1,266,000	70.0	380,000	7.4	2,812,000	500,000	19.0	9,500,000
1908	988,000	6.5	924,000	11.0	10,164,000	750,000	28.9	21,675,000
1909	929,000	27.5	555,000	9.1	5,050,000	615,000	18.7	11,500,000
1910	1,295,000	3.3	1,252,000	15.0	18,780,000	695,000	35.0	24,325,000
Average					10,342,000			21,256,000

If we average the 5-year period and calculate the loss on this basis for 1907, it will be seen that the total crop for Kansas, Oklahoma, and Texas fell about 50,000,000 bushels short of this average—both wheat and oats being considered. Seventy per cent of the Texas wheat acreage was abandoned.

This does not represent the loss as it actually occurred in various parts of the States, as some parts of each State were more badly affected than others and the good parts would bring up the yield for the poorer portions. Sumner County, Kans., is a good illustration of this. It is located in the extreme southern portion of the State and was in the badly infested districts. To quote from a letter from Mr. George H. Hunter, of Wellington, Kans., dated February 6, 1908:

I wish to explain that our crop of winter wheat in Sumner County for the year 1907 amounted to 1,909,574 bushels; this is our latest estimate, while the general average is about four and one-half million bushels for Sumner County, and that would be a safe basis for you to figure on. According to our acreage last year, if it had not been for the green bugs, I think we would have had at least four to four and one-half million bushels of wheat.

THE SITUATION IN 1911.

The winter and spring of 1910–11 west of the Mississippi River, but not east of it, was such as would tend to bring about another invasion from the pest. Some injury was reported, accompanied by specimens, from Pecos River valley in southeastern New Mexico. Mr. J. T. Monell of this bureau, however, visited the locality in April and reported the pest as having disappeared without doing serious injury. The material received was almost universally parasitized by *Aphidius testaceipes* Cress., which probably overcame the Toxoptera before its occurrence reached the magnitude of an invasion.

There was also a limited incipient outbreak in eastern Oklahoma, which was investigated by Mr. Kelly. Here, too, the parasites apparently gained supremacy before serious injury was done, except perhaps in a few isolated cases.

There is little doubt that the unusual and excessively high temperature for even a mild winter that prevailed throughout the Southwest during a portion of the winter months was sufficient to revive the parasites as well as to aid their host, and thus bring about conditions that enabled the parasites to prevent the aphidids from increasing in numbers to a point where they were beyond their control.

FOOD PLANTS.

This insect has a very wide range of host plants and can on that account find fresh food at any season of the year. In this way it is enabled to perpetuate itself over vast areas of country and under almost every variety of climate.

Rondani, who first described the species in 1852, gives the following list of host plants: Oats (*Avena sativa*); wheat (*Triticum vulgare*); spelt (*Triticum spelta*); *Arrhenatherum elatius* (*Avena elatior*); couch grass (*Triticum repens*); *Hordeum murinum; Lolium perenne; Capriola* (*Cynodon*) *dactylon;* soft chess (*Bromus hordeaceus*) (*mollis*); and corn (*Zea mays*). He states also that Toxoptera had been found quite abundant upon the foliage of rice (*Oryza sativa*) and common barley (*Hordeum vulgare*). We find no other references to its being found upon rice. In 1863 Passerini adds sorghum (*Andropogon* sp.) and he also observed it on barley.

Macchiati, in 1882, added the following hosts: *Dactylis glomerata, Bromus erectus,* and *B. villosus* (*maximus*); in 1883 he added *Triticum villosum, Avena fatua,* and *A. barbata;* in 1885, *Poa annua.*

Del Guercio, in 1906, mentions it as occurring upon buckwheat (*Fagopyrum esculentum*). This is the first and only reference we have found in which it has been accused of infesting plants other than those belonging to the Gramineæ.

Toxoptera was first observed upon wheat and oats in the United States. In 1889 the senior author observed it feeding upon rye and in 1890 he found it plentiful at Lafayette, Ind., upon *Dactylis glomerata.* In 1907 he found it destructively abundant upon the same grass at Midlothian, Va. This infested field was from 4 to 5 miles from wheat, oats, or rye fields. In Insect Life,[1] he states that Toxoptera will live upon the leaves of all kinds of grains, including corn, during summer. In 1902 he found Toxoptera feeding upon cheat (*Bromus secalinus*) and rye grass (*Elymus canadensis*) at Peotone, Ill.

The junior author found it quite abundant on volunteer corn plants among oats on April 2, 1907, at Hobart, Okla. A cornfield near a badly infested wheat field was found to be suffering also. Mr. C. N. Ainslie of this bureau, on April 4 of the same year, at Kingfisher, Okla., found a cornfield that was seriously injured by Toxoptera. Farmers in Oklahoma were very much disturbed over the prospect that the corn also would be swept away by the "green bug," but later developments proved that it was not a serious pest to corn. The junior author found *Hordeum pusillum* and *Alopecurus geniculatus* badly infested on April 12 at Kingfisher, Okla., and *Agropyron occidentale* was found harboring the pest in large numbers at Hooker, Okla., in May. The senior author, Mr. Ainslie, and Prof. E. A. Popenoe,

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[1] Insect life, Div. Ent., U. S. Dept. Agr., vol. 4, p. 245.

of Kansas, also found the *Hordeum pusillum* much infested later in the season. In July there was an outbreak of Toxoptera on bluegrass (*Poa pratensis*) on the grounds of the United States Department of Agriculture, Washington, D. C. Later in the season the junior author found it on bluegrass in the fields about Richmond, Ind. In the fall of the same year (1907) this was the only plant on which the sexes and eggs could be found. In fact, for Indiana, Illinois, Ohio, and more northern localities bluegrass appears to be the normal host, and the "green bug" is readily found upon it at any time in the year even when it can be found only sparingly upon any other plant.

A number of new host plants were added to the list in 1908. Mr. Kelly, of this Bureau, found Toxoptera feeding freely in the fields upon *Hordeum jubatum* and *Distichlis spicata* in Montana and upon a species of Andropogon in Colorado. Mr. Ainslie found it breeding freely in the fields upon *Hordeum jubatum, H. cæspitosum, H. nodosum, Elymus striatus, Agropyron tenerum, Bromus unioloides, B. porteri, Stipa viridula,* and *Polypogon monspeliensis* about Artesia, N. Mex. In one instance Mr. Ainslie found several alfalfa plants (*Medicago sativa*) with colonies of Toxoptera upon them, as many as 21 specimens being observed on a single leaf. This seems very unusual and we have no other records of its occurrence on this plant. Prof. C. P. Gillette, of Fort Collins, Colo., found it infesting *Agropyron occidentale,* and in 1907 he found it feeding upon bluegrass. During the summer of 1908 Toxoptera was found by the junior author to breed freely upon *Dactylis glomerata, Eleusine indica, Eragrostis pilosa, E. megastachya, Sporobolus neglectus, Agropyron repens, Elymus virginicus, E. canadensis,* and *Bromus secalinus,* in his rearing cages at Richmond, Ind.

In 1909 and 1910 a few more plants were added to the list. Mr. Ainslie found it breeding freely upon *Hordeum murinum* in Arizona and upon *Agropyron occidentale* in New Mexico. Mr. Kelly found it breeding freely upon millet (*Chætocloa italica*) and upon Japanese millet (*Echinochloa crus-galli*) in Kansas. Mr. Harper Dean, jr., then of this bureau, found it feeding upon *Stipa leucotricha* in Texas. Mr. T. D. Urbahns, of this bureau, found that it bred readily in his cages at Dallas, Tex., upon Bermuda grass (*Capriola dactylon*), *Chætochloa viridis,* Johnson grass (*Sorghum halepense*), and upon rice (*Oryza sativa*).

During the summer of 1909 Mr. T. H. Parks, of this bureau, and the junior author observed that Toxoptera bred freely upon *Elymus striatus, Juncus tenuis, Poa compressa, Bromus commutatus, B. tectorum* (?), *B. inermis,* sheep's fescue (*Festuca ovina*), hard fescue (*F. duriuscula*), meadow fescue (*F. elatior*), various-leaved fescue

(*F. heterophylla*), *F. rubra*, *Agropyron occidentale*, and Italian rye grass (*Lolium multiflorum*), in their rearing cages at Lafayette, Ind.

The following is a complete tabulated list of host plants[1] to date, in so far as our records show.

IN EUROPE.

Barley.
Corn.
Oats.
Rice.
Wheat.
Spelt.
Sorghum.
Agropyron (*Triticum*) *repens.*
Avena barbata.
Avena elatior=Arrhenatherum elatius.
Avena fatua.
Bromus erectus.
Bromus maximus=B. villosus.
Bromus mollis=B. hordeaceus.
Capriola (*Cynodon*) *dactylon.*
Dactylis glomerata.
Fagopyrum esculentum.
Hordeum murinum.
Lolium perenne.
Poa annua.
Triticum villosum.

IN AMERICA.

Barley.
Corn.
Oats.
Rice.
Rye.
Sorghum.
Spelt.
Wheat.
Alfalfa (*Medicago sativa*).
Agropyron occidentale.[2]
Agropyron repens.
Agropyron tenerum.[2]
Alopecurus geniculatus.[2]
Cheat (*Bromus secalinus*).[2]
Bromus commutatus.[2]
Bromus inermis.[2]
Bromus porteri.[2]
Bromus tectorum (?).[2]
Bromus unioloides.[2]
Capriola dactylon.
Chætochloa italica.
Chætochloa viridis.[2]
Dactylis glomerata.
Distichlis spicata.[2]
Echinochloa crus-galli.[2]
Eleusine indica.[2]
Elymus canadensis.[2]
Elymus striatus.[2]
Elymus virginicus.[2]
Eragrostis megastachya.[2]
Eragrostis pilosa.[2]
Festuca duriuscula.[2]
Festuca heterophylla.[2]
Festuca ovina.[2]
Festuca elatior.
Festuca rubra.[2]
Holcus halpensis.[2]
Hordeum cæspitosum.[2]
Hordeum jubatum.[2]
Hordeum murinum.
Hordeum nodosum.[2]
Hordeum pusillum.[2]
Juncus tunuis.[2]
Lolium multiflorum.[2]
Poa compressa.[2]
Poa pratensis.[2]
Polypogon monspeliensis.[2]
Sporobolus neglectus.[2]
Stipa leucotricha.[2]
Stipa viridula.[2]

[1] During 1909 Mr. C. P. v. d. Merwl, Bloomfontein, Orange Free State, Africa, wrote us that he had found *Toxoptera graminum* attacking "Bermuda grass" and their native blue-grass (*Andropogon hirtus*).

[2] These are host plants not previously recorded.

CHARACTER OF ATTACK.

The actual effect upon the plant, whether chemical or physiological, is not clearly understood. If a few Toxoptera be placed upon a perfectly healthy plant, in a few days the tissue in the immediate vicinity of the aphidids will take on a yellowish tinge; if the aphidids remain in one place for a considerable time and increase in numbers, the whole plant gradually turns yellow and dies, the leaves changing to reddish brown.

When the original source of infestation arises from some one or more points within a field, as described elsewhere in this paper, the plants take on a yellowish color in small, almost circular areas, (Pl. I, fig. 2) and as the Toxoptera increase in numbers the plants in the center die, becoming reddish brown, and the aphidids work outward in every direction from the center, gradually enlarging the spot until it may cover many acres. When a field is infested from without by migrating forms, the aphidids appear to spread evenly over the entire field and the whole gradually turns yellow, and in cases of severe outbreaks a whole field may die simultaneously. (See Pl. I, fig. 1.) These aphidids are essentially leaf-feeders, rarely if ever being found injuring the heads or fruiting parts of the plant.

Toxoptera appears to have a more strikingly disastrous effect upon wheat or oats plants than any of the other common grain aphidids. Seemingly when in no greater numbers than other species the plants will succumb more quickly to the attack of Toxoptera.

VIVIPAROUS DEVELOPMENT.

Toxoptera graminum, as already shown, has been found to breed over a wide range of country, and its behavior, under the varying temperatures and climatic conditions prevailing over this vast territory, presents and opens up a broad field for investigation.

IN THE SOUTH.

In northern latitudes the normal manner of reproduction among the Aphididæ is both sexually and asexually. In southern latitudes hese conditions, apparently, do not obtain, as here the normal means of reproduction seems to be asexually, each generation being composed entirely of viviparous females.

South of about the thirty-fifth parallel, except in high altitudes, it appears that Toxoptera breeds continuously throughout the year without the appearance of the true sexes. April 6, 1906, Mr. George I. Reeves, of this bureau, found the eggs of a plant-louse on wheat at Nashville, Tenn., and Mr. Kelly found males (fig. 6), females, and eggs of Toxoptera at Knoxville, Tenn., in December, 1908. The eggs found by Mr. Reeves may have been those of Toxoptera, but we

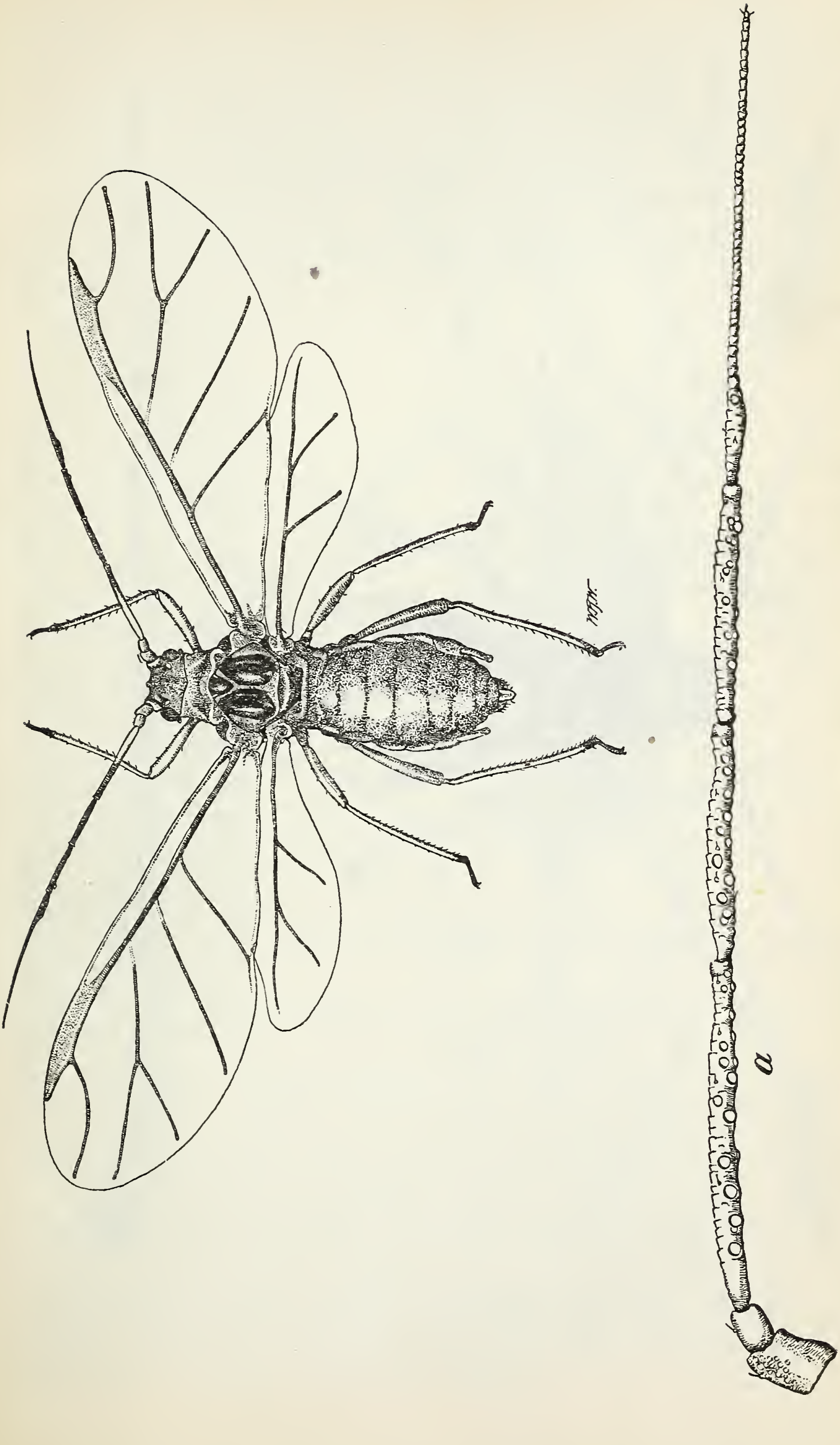

FIG. 6.—The spring grain-aphis (*Toxoptera graminum*): Male and antenna. Enlarged; actual size, 1.5 mm. (Original.)

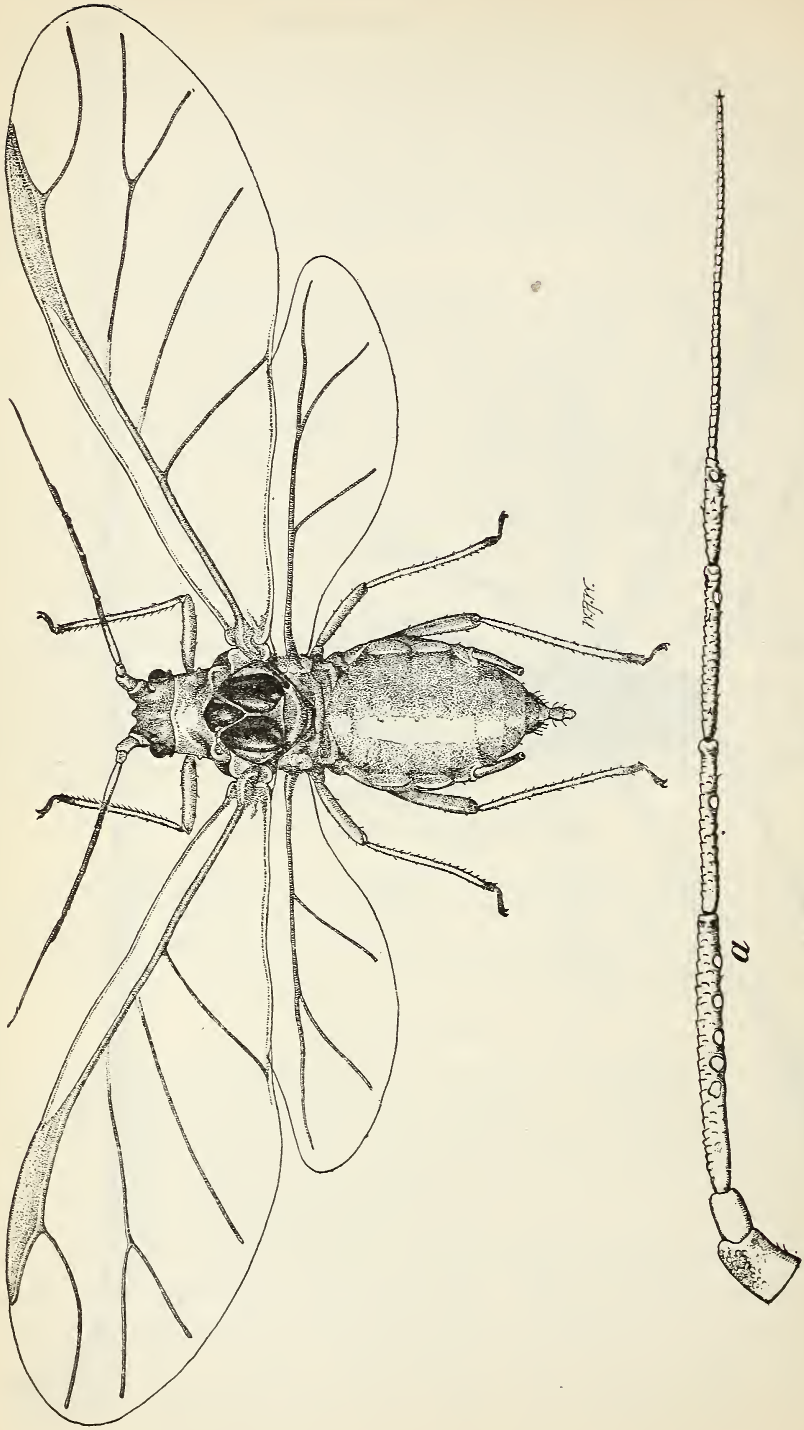

Fig. 7.—The spring grain-aphis: Winged viviparous female and antenna. Enlarged; actual size, 1.9 mm. (Original.)

can not be sure of the species as they were not reared. Winged and wingless viviparous females (figs. 7, 8) were, however, present at the time the eggs were found, as were also those of both Aphis (Siphocoryne[1]) and Macrosiphum. Mr. E. Dwight Sanderson obtained the males and oviparous females of *Macrosiphum granaria* Buckt. in Texas but only artificially in his rearing cages. Mr. R. A. Vickery, of this bureau, found males, females, and eggs of *Aphis maidi-radicis* Forbes at Salisbury, N. C. These instances mentioned above are probably the most southerly points at which oviparous forms of plant-lice have so far been found in the United States.

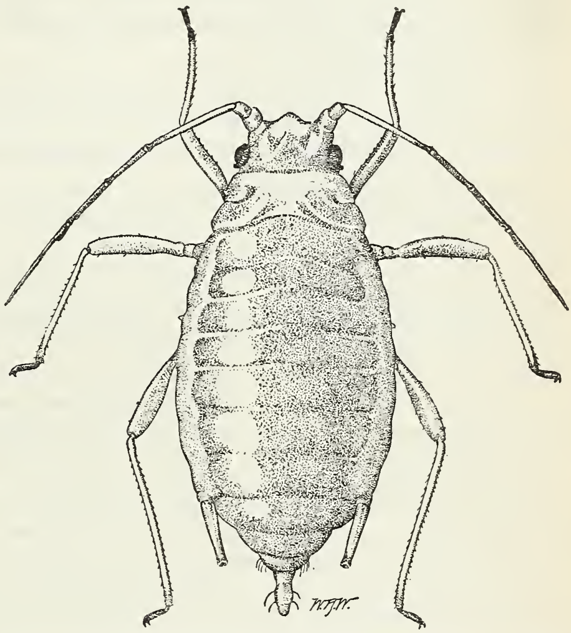

FIG. 8.—The spring grain-aphis: Wingless viviparous female. Enlarged; actual size, 2 mm. (Original.)

In the Southern States, wherever there is sufficient food, Toxoptera apparently breeds viviparously throughout the year; for this reason the number of generations here, other things being equal, should far exceed that in the Northern States. As a matter of fact, however, the dry, hot, protracted summers of the Southwest are probably disastrous to the species during the hot months, except perhaps in secluded nooks, where there is a supply of succulent host plants.

In northern Texas, as observed by Mr. Urbahns, during June of 1909, Toxoptera rapidly disappeared with the ripening of the grain crops and the approach of hot weather. Winged forms migrated with the breeze early in this month, and wingless forms soon perished from extreme heat and a shortage of green food in the field. Observations clearly showed that it was almost impossible for the "green bug" to live and reproduce in grain fields during the summer. While

[1] Probably *Siphocoryne avenæ* Fab. The use of the generic name Siphocoryne, as applied to this species, is questionable, and is not at present followed by many, perhaps the major portion, of the students of the Aphididæ. According to Schouteden (Ent. Soc. Belgique, vol. 12, p. 217, 1906, Catalogue Aphides de Belgique) it should be Aphis. Some of our best students, however, admit that this particular species, *avenæ*, is on the borderland between Siphocoryne and Aphis.

the temperature was above and precipitation below normal, during this particular season, the effect was so evident that there is reason to believe that under normal conditions these aphidids do not live in fields directly exposed to the sun during the summer months.

The table on pages 64–69 on daily reproduction, length of reproductive period, and longevity show a decided decrease in all of these for the summer months over those of spring and fall. The facts upon which these figures were based could be secured only by protecting the aphidids from exposure to the hot summer sun. Aphidids exposed without such protection were unable to live through the season, though special care was taken to furnish them with a supply of green food plants.[1]

Mr. Urbahns secured the following results by removing Toxoptera, together with its green food plants, from a shaded position and subjecting it to the temperature of loose, unshaded soil.

August 18, with the soil temperature at 145° F. in the sun, 12 Toxoptera on a wheat plant were exposed 30 seconds; 5 fell to the ground dead, 7 remained on the plant dead.

Three adults and 4 young on a wheat plant were similarly exposed for 30 seconds, after which time all were dead.

One winged and 4 wingless adults on a wheat leaf were exposed for 30 seconds, when they were found to be dead on the plant.

Thirteen adult aphidids on wheat plants were exposed for 15 seconds, 5 fell to the ground dead. After 30 seconds exposure the plant was removed to the shade; 6 more were then dead on the plant and 2 were alive between the leaves.

Soil temperature 118° F. (shaded by cloud). Nine aphidids on a wheat plant were exposed for 30 seconds, 2 died, and 7 remained alive.

A potted wheat plant bearing several hundred aphidids, the temperature being 114° F. in the shade, was removed from the shade for 5 minutes. A large percentage of the aphidids fell to the ground, some survived, but many died.

A potted wheat plant bearing several hundred aphidids was kept in the shade where the maximum temperature was 114° F. Next morning many of the aphidids were dead.

When the soil temperature was 116° F. shaded by a thin cloud, 3 aphidids on a plant were exposed for 60 seconds, 1 died, and 2 remained alive.

August 19, the soil temperature being 128° F. in the sun, 12 aphidids on a young plant were exposed for 30 seconds; 5 fell from the plant and died, while the other 7 were dead on the plant.

When the soil temperature was 130° F. in the sun 12 aphidids on a young plant were exposed for 20 seconds. All were then dead.

When the soil temperature was 128° F. in the sun 11 aphidids on a plant were exposed for 30 seconds; at the end of this time all were dead—4 fell to the ground, and 7 remained on plant.

At a soil temperature of 130° F. in the sun 8 aphidids on a plant were exposed for 15 seconds; all were then dead—3 fell to the ground, and 5 remained on the plant.

The results of these experiments prove that Toxoptera can not survive the summer in the open fields in sections of the country where the pest commits its most serious ravages with the greatest

[1] Mr. J. T. Monell suggests that this may be due as much or more to the hot, dry air as to the direct rays of the sun.

frequency. They also account for our inability to locate it in such territory during the summer months.

A careful search was made at different times for grasses that were actually serving as summer food plants. The only hope of finding such was in well shaded spots along streams, where, from all indications, Toxoptera would be sufficiently protected to live and reproduce throughout the summer.

At Plano, Tex., Toxoptera was rapidly disappearing from the fields in early June. By June 14 there was only a limited number of plants which still supported the remaining few of these aphidids and the latter were soon carried away by ants. When confined on green food plants and protected from their enemies by a large frame covered with thin cheesecloth Toxoptera lived until July 3. After this date it was apparently too hot for their existence. Out in the open, where young wheat and oats plants were sustained by frequent watering, they lived until July 15. After this date they apparently could not endure the summer temperature and no more were found. Since no reinfestation appeared up to November 30, it was quite evident that the aphidids had all perished.

On June 28 viviparous forms of this species were found rather abundantly in a small field of oats at McAlester, Okla. This field of a few acres in size was on the east slope of a rocky hill. A natural growth of timber surrounded the field and a few trees grew in its midst where rocks make cultivation impossible. Green vegetation was abundant in shaded places and along the creek one-half mile to the east. Conditions of this sort are certainly favorable for Toxoptera to live and reproduce throughout the summer as long as they find the food plants present. While these spots, favorable to Toxoptera, are characteristic of eastern Oklahoma, where, as has been stated, an incipient outbreak of the pest actually occurred in 1911, they are also found along streams in the central part of that State and in northern Texas. As there appears to be no resting or egg stage in the South, whenever there is a warm open winter these aphidids become very abundant and threaten the grain crops of this region.

IN THE NORTH.

Farther north, in the vicinity of Lafayette, Ind., viviparous reproduction is confined to the months of April, May, June, July, August, September, October, and November. During mild winters, however, the species may breed viviparously throughout the year, as the senior author found it breeding in the open throughout January, February, and March, 1890, notwithstanding the fact that on January 24 the temperature fell as low as + 3° F.; on February 9, to + 6° F., and on March 6 to + 4° F. It appears that a temperature of about

zero, with no protection, is fatal to Toxoptera, except to the egg, but the fact that it withstood the winter in 1890 can easily be accounted for. That winter was unusually mild throughout, with the exception of the dates mentioned, and if one consults the weather records it

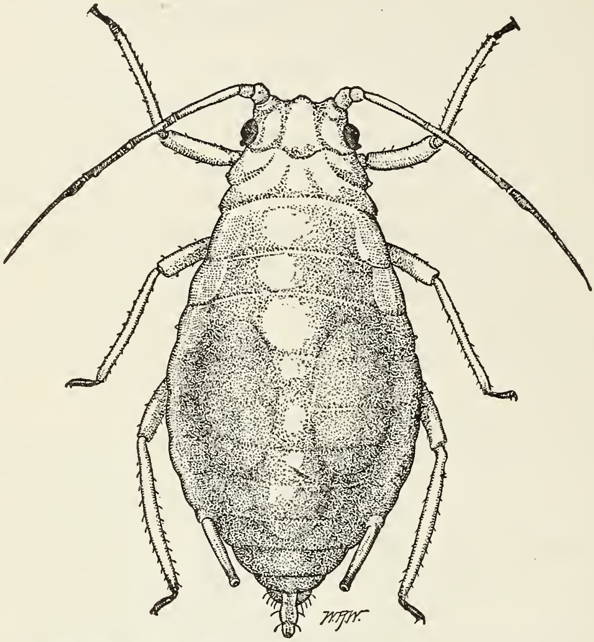

FIG. 9.—The spring grain-aphis: Oviparous female, showing eggs within the abdomen. Enlarged; actual size, 2.25 mm. (Original.)

will be found that on January 24 there were 3.5 inches of snow, February 9, 3.4 inches, and March 6, 4 inches. The covering of snow in each instance would appear to have been sufficient to protect the Toxoptera, as on December 8, 9, and 10, 1909, at Lafayette, Ind., the temperature fell as low as from $-1°$ F. to $-4°$ F. below zero, and plant-lice of all kinds, in the rearing cages out of doors, were killed, while those in a near-by wheat field, covered with several inches of snow, were found to be in good condition on December 13, at which time the cold spell was broken and the ground began to thaw.

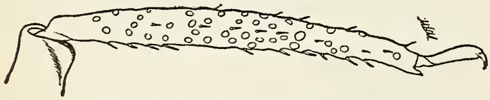

FIG. 10.—The spring grain-aphis: Hind tibia of oviparous female. Greatly enlarged. (Original.)

As a rule, Toxoptera breeds slowly in October and November, at which time the majority become oviparous females (figs. 9, 10) and males (fig. 6).

REARING METHODS.

All of the rearing work, unless otherwise stated in the text, was conducted out of doors under as nearly normal conditions as it was possible for us to secure. The wheat plants on which the Toxoptera were confined were grown in flowerpots and covered with lantern globes, over the top of which was drawn a very thin fabric commercially known as swiss. The pots were placed on a rearing stand having one side hinged in such a manner that it could be let down in fair weather and closed up in case of gales or severe beating storms. This stand with its contents is illustrated in Plate II, figure 1. A thermograph was placed in this stand, and thus continuous records of temperature were secured.

In the middle of the summer of 1907 two series of investigations were begun and were continued until December to determine the number of generations. In both 1908 and 1909 series of generation studies were begun in spring with the egg (fig. 11) and continued until the egg-laying forms appeared in the fall. In making these observations, the first individuals to hatch from the eggs in the spring were isolated; the first-born from these were in turn isolated, and this process was continued throughout the season until the egg-laying forms appeared. The last-born was also kept and the same mode of procedure continued until fall, as was the case in the line of the first-born. All young other than the first-born of the first series and the last-born of the second series were counted each day and destroyed. In this manner, each series being considered, we would arrive at the maximum and minimum number of generations. During these three years a vast amount of data, besides that on the number of generations, was thus accumulated. (See table, pp. 52–57.)

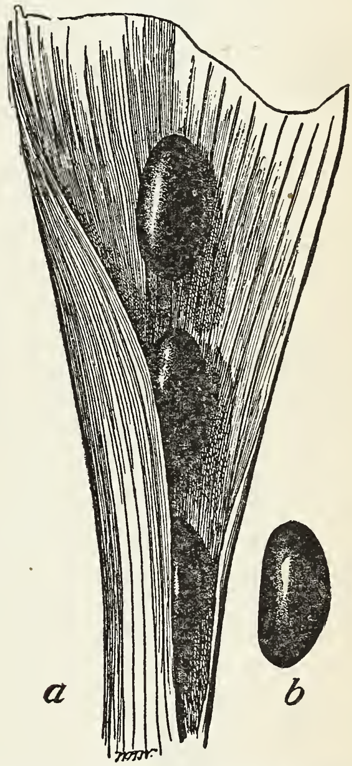

FIG. 11.—The spring grain-aphis: Eggs as deposited on leaf: *a*, Dorsal view; *b*, lateral view. Greatly enlarged. (Original.)

First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.

[*b*=born. —=died or disappeared.]

Date (1908).	Temperature.		First-born generation series.																					Last-born generation series.								
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Twentieth generation.	Twenty-first generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.
	°*F.*	°*F.*																														
Mar. 27	78	53	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	75	51	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	51	36	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	46	30	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	53	41	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Apr. 1	59	47	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	59	29	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	42	24	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	63	29	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	59	45	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	68	36	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	70	45	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	68	40	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	55	35	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	60	46	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	59	42	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	62	27	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	74	34	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	77	47	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	71	57	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	57	31	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	65	32	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	63	55	2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	70	50	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	68	39	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	68	33	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	79	35	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	79	52	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	71	60	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	74	61	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	80	53	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	67	42	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	54	38	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	46	36	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

	30	47	33	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
May	1	56	29	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	2	47	35	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	3	55	37	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	4	50	41	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	5	52	49	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	6	76	49	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	7	63	41	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	8	49	41		0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	9	65	42	5	2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	10	73	44		1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	11	76	45	8	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	12	80	60			0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	13	80	55		6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	14	84	57			0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	15	85	59	3	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	16	86	52	2	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	17	87	54	2	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	18	77	61			2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	19	68	54	5	7	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	20	76	54				0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	21	79	50	1	3	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	22	81	57	1	1	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	23	83	58	0	2	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	24	85	55	0	4	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	25	92	55	0			0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	26	86	66	1	5	8	2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*b*	...	...	...	...	...	...	...	...	...
	27	88	57	0			4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
	28	90	57	—	1	2	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
	29	90	62	...	1	3	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
	30	78	62	...	2	1	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
	31	71	55	...	0	3	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
June	1	64	43	...	1			0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
	2	76	43	...	0	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...
	3	70	52	...	0	4	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	...	...	...	...	...	...	...	...	...
	4	82	61	...	1			2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...
	5	84	50	...	1	3	6	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
	6	87	55	...				6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...
	7	90	60	...	1	1	4	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	...	...	...	...	...	...	...	...	...
	8	86	64	...	0	0	6	10	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	...	...	...	...	...	...	...	...	...
	9	78	64	...	0	3			0	...	...	...	...	...	...	...	...	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...
	10	77	54	...	0	1	2	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	...	...	...	...
	11	72	43	...	0	1	2	...	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	*b*	...	...	...	...	...	...	...	...
	12	82	51	...	0	0	1	...	4	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	...
	13	88	59	...	0	0	3	...	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	...
	14	70	58	...	0	1	2	...	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	...
	15	64	45	...	0			...	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	...
	16	74	30	...	0	2	0	...	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	—	0	...	...	...	...	...	...	...	...
	17	82	47	...	0	0	2	...	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...
	18	90	65	...	—	0	1	...	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...
	19	91	66	...	...	1	3	...	12	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...
	20	89	65	...	...			...		3	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...
	21	89	65	...	...	1	2	...	7	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...

First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.—Continued.

Date (1908).	Temperature.		First-born generation series.																					Last-born generation series.								
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Twentieth generation.	Twenty-first generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.
	°F.	°F.																														
June 22	91	64	....	....	0	0	....	5	6	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	....	....	....	....	....	....	....
23	93	68	....	....	0	0	....	3	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	....	....
24	94	67	....	....	0	0	....	4	8	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....		....	....	....	....	....	....	....
25	79	52	....	....	—	0	....			0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	5	b	....	....	....	....	....	....
26	79	49	....	....	....	0	....	2	7	4	b	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	....	....	....	....	....	....
27	88	48	....	....	....	—	....			1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	—	0	....	....	....	....	....	....
28	89	52	....	....	....	....	....	—	4	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
29	81	60	....	....	....	....	....	....	4	8	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
30	82	54	....	....	....	....	....	....			0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
July 1	89	52	....	....	....	....	....	....	4	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
2	89	57	....	....	....	....	....	....	4	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
3	82	64	....	....	....	....	....	....		1	2	b	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
4	82	66	....	....	....	....	....	....	1	—	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....
5	88	60	....	....	....	....	....	....	4	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....
6	91	66	....	....	....	....	....	....	1	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	....
7	80	64	....	....	....	....	....	....	2	....	8	0	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	....
8	78	48	....	....	....	....	....	....	0	....	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	....
9	84	47	....	....	....	....	....	....	—	....	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....	....
10	88	51	....	....	....	....	....	....	....	....	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	2	b	....	....	....	....	....
11	91	54	....	....	....	....	....	....	....	....	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	0	....	....	....	....	....
12	95	67	....	....	....	....	....	....	....	....	9	2	b	....	....	....	....	....	....	....	....	....	....	....	....	0	0	....	....	....	....	....
13	92	63	....	....	....	....	....	....	....	....		2	0	....	....	....	....	....	....	....	....	....	....	....	....	—	0	....	....	....	....	....
14	86	65	....	....	....	....	....	....	....	....	3	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....
15	79	57	....	....	....	....	....	....	....	....	3	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....
16	87	54	....	....	....	....	....	....	....	....	3	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....
17	90	66	....	....	....	....	....	....	....	....			0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....
18	84	71	....	....	....	....	....	....	....	....	6	2	3	b	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....	....
19	80	60	....	....	....	....	....	....	....	....			0	0	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....
20	77	59	....	....	....	....	....	....	....	....	2	—	5	0	....	....	....	....	....	....	....	....	....	....	....	....	4	....	....	....	....	....
21	75	66	....	....	....	....	....	....	....	....	0	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
22	88	57	....	....	....	....	....	....	....	....	1	....	2	0	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....
23	93	61	....	....	....	....	....	....	....	....	0	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....
24	86	66	....	....	....	....	....	....	....	....	2	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	1	b	....	....	....	....
25	85	64	....	....	....	....	....	....	....	....	0	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	—	0	....	....	....	....
26	87	65	....	....	....	....	....	....	....	....	0	....	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
27	89	66	....	....	....	....	....	....	....	....	0	....	3	2	b	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
28	87	60	....	....	....	....	....	....	....	....	—	....	3	2	0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....

29	88	62											4	2	0													0				
30	91	63											3	1	0													0				
31	91	60											4	0	0													2				
Aug. 1	86	54											1	1	0													0	b			
2	93	53											—	—	0													—	0			
3	93	55													0														0			
4	93	64													3	b													0			
5	82	67													6	0													0			
6	86	58														0													0			
7	79	69													4	0													0			
8	75	55													3	0													0			
9	81	50													2	0													0			
10	82	54														0													3			
11	88	55													3	0													3			
12	90	69													6	3	b												2			
13	80	67														3	0															
14	90	60													2	4	0												0			
15	89	61													2	1	0												3			
16	95	65													2	6	0												2			
17	93	67															0															
18	85	58													—	3	2	b											5			
19	95	52														2	1	0											1			
20	77	56														3	3	0											1			
21	86	47														0	3	0											0			
22	86	60														4	3	0											1			
23	83	53														0	1	0											0			
24	80	50														2	2	0											2			
25	83	53														—	1	0											1			
26	81	54															0	0											1			
27	82	51															—	0											2	b		
28	84	45																0											0	0		
29	93	51																0											0	0		
30	93	62																0											0	0		
31	95	54																2	b										—	0		
Sept. 1	90	56																3	0											0		
2	77	46																1	0											0		
3	78	37																	0											0		
4	81	48																0	0											0		
5	86	50																1	0											0		
6	89	53																4	0											0		
7	74	46																	0											0		
8	82	40																1	0											2		
9	90	44																1	0											1		
10	93	50																1	3	b										2		
11	94	51																—	3	0										2		
12	94	54																	2	0										2		
13	89	57																	2	0										2		
14	84	49																	3	0										2		
15	84	56																	1	0										1		
16	85	52																	1	0										4		
17	87	50																	1	0										2		
18	91	48																	5	0										4		
19	93	50																		3	b											

First and last born generation series from an individual that hatched from the egg Mar. 27, 1908. Richmond, Ind.—Continued.

Date (1908).	Temperature.		First-born generation series.																					Last-born generation series.								
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Twentieth generation.	Twenty-first generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.
	°F.	°F.																														
Sept. 20	95	50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	3	0	...	...	...	...	...	...	...	...	5	...	...
21	95	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			0	...	...	...	...	...	...	...	...		...	...
22	91	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	1	0	...	...	...	...	...	...	...	...	2	...	...
23	90	53	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3	0	...	...	...	...	...	...	...	...	1	...	...
24	93	53	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	3	0	...	...	...	...	...	...	...	...	3	...	...
25	92	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	0	0	...	...	...	...	...	...	...	...	2	...	...
26	90	57	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		1	0	...	...	...	...	...	...	...	...	2	...	...
27	87	54	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	3	0	...	...	...	...	...	...	...	...	4	b	...
28	76	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			0	...	...	...	...	...	...	...	...	0	0	...
29	53	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			0	...	...	...	...	...	...	...	...	0	0	...
30	74	33	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			2	b	...	...	...	...	...	...	...	0	0	...
Oct. 1	62	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	1	0	...	...	...	...	...	...	...	0	0	...
2	57	25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	1	0	0	...	...	...	...	...	...	...	0	0	...
3	69	27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	1	0	0	...	...	...	...	...	...	...	0	0	...
4	79	27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	0	0	...	...	...	...	...	...	...	0	0	...
5	86	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	1	2	0	...	...	...	...	...	...	...	0	0	...
6	83	39	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	0	...	...	...	...	...	...	...	0	0	...
7	76	42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	1	0	...	...	...	...	...	...	...	0	0	...
8	60	41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	0	...	...	...	...	...	...	...	0	0	...
9	60	37	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		0	0	...	...	...	...	...	...	...	0	0	...
10	65	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	1	0	...	...	...	...	...	...	...	0	0	...
11	51	39	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	0	...	...	...	...	...	...	...	0	0	...
12	59	25	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	0	...	...	...	...	...	...	...	0	0	...
13	73	26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	—	0	...	...	...	...	...	...	...	0	0	...
14	74	38	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	0	...	...	...	...	...	...	...	0	0	...
15	79	46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	...	0	...	...	...	...	...	...	...	0	0	...
16	78	42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	0	...	...	...	...	...	...	...	0	0	...
17	81	39	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		...	0	...	...	...	...	...	...	...	0	3	b
18	84	46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	...	0	...	...	...	...	...	...	...	0	6	0
19	75	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	b	...	...	...	...	...	...	0		0
20	77	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	0	3	0
21	79	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	0		0
22	72	40	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	0	1	0
23	66	50	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	0	2	0
24	68	55	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	0	...	...	...	...	...	...	0	2	0
25	59	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	0	0	0

26	62	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	—	0	0
27	56	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	2	0
28	55	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	0	0
29	56	29	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	0	0
30	50	26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	0	0
31	47	17	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	0	0
Nov. 1	49	21	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	...	...	...	...	...	...	...	0	0
2	55	35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	0	...	...	...	...	...	...	...	0	0
3	66	37	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	0	0
4	62	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	0	0
5	40	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	0	0
6	61	29	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	—	0
7	58	24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	0
8	57	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	0
9	52	31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	(1)
10	43	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
11	43	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
12	38	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
13	33	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
14	29	18	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
15	39	24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
16	35	24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
17	52	13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
18	58	43	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
19	60	27	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
20	67	35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
21	56	22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
22	66	35	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
23	66	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...
																							(1)									

[1] Adult oviparous. ♀

STEM MOTHERS.

At both Richmond and La Fayette, Ind., the eggs begin to hatch the latter part of March and continue until about April 10. The first generation, or stem mothers, differs from the next generation slightly in coloration, and there are besides some slight structural differences. The measurements of the body are not included in the following description, as the specimens are mounted in balsam.

DESCRIPTION OF THE DIFFERENT INSTARS.

First instar.—Before first molt: General color, very dark Nile green; head, beak, antennæ, legs, and cornicles very dark gray; tips of the antennæ, the tarsi, and the eyes black. Antennæ 4-segmented.

Measurements of antennal joints (average from 2 specimens): I, 0.034 mm.; II, 0.034 mm.; III, 0.093 mm.; IV, base, 0.046 mm.; IV, filament, 0.114 mm.; total length, 0.321 mm.

Second instar.—Before second molt: General coloration of head and body lighter than in the preceding stage, otherwise the coloration the same. Antennæ 5-segmented.

Measurements of antennal joints (average from 3 specimens): I, 0.045 mm.; II, 0.039 mm.; III, 0.127 mm.; IV, 0.082 mm.; V, base, 0.066 mm.; V, filament, 0.161 mm.; total length, 0.520 mm.

Third instar.—Before third molt: The color of the body now varies from pale green to deep apple green; head concolorous with body; legs slightly lighter; eyes, tip of beak, tip of cornicles, articulation of femora, and tibiæ black; distal two-thirds of antennæ black; basal portion greenish gray. Antennæ 5-jointed.

Measurements of antennal joints (average from 4 specimens): I, 0.050 mm.; II, 0.045 mm.; III, 0.152 mm.; IV, 0.093 mm.; V, base, 0.072 mm.; V, filament, 0.174 mm.; total length, 0.586 mm.

Fourth instar.—Before fourth molt: General coloration variable, though about the same as in third instar, with the exception that the eyes of the young begin to show through the body wall; eyes and tip of beak black; legs greenish gray, the articulation of femora and tibiæ and the distal portion of tibiæ very dark, and tarsi black; cauda lighter than the body, as is sometimes also the head; the two distal segments and distal portion of third segment of antennæ black, gradually shading off until at the base they are concolorous with the head; cornicles black at tips, shading off into pale grayish green at base. Antennæ 5-jointed; sometimes, however, there are 6 distinct joints.

Measurements of antennal joints (average from 4 specimens): I, 0.065 mm.; II, 0.051 mm.; III, 0.194 mm.; IV, 0.119 mm.; V, base, 0.088 mm.; V, filament, 0.196 mm.; total length, 0.713 mm.

Fifth instar.—In the adult stage the color varies from a clay yellow to greenish yellow and deep apple green; there is no central dorsal stripe; the eyes of the young show through the body walls. In some of the greener specimens the head is slightly lighter and in some of the lighter colored specimens the head is slightly darker than the body; eyes and tip of beak black; legs pale greenish gray, the articulation of femora and tibiæ and the distal third of tibiæ quite dark; tarsi black; cauda in yellow specimens with a yellowish tint and in the deep green specimens somewhat grayish, shape and length same as in summer form; cornicles concolorous with body except the distal third, which is black, shape and length same as in summer form; three distal segments of antennæ and distal half of fourth black, the basal joints concolorous with the head. Antennæ 6-segmented, though two specimens were found in which one antenna of each was only 5-segmented.

Measurements of antennal joints (average from 16 specimens): I, 0.066 mm.; II, 0.049 mm.; III, 0.226 mm.; IV, 0.140 mm.; V, 0.152 mm.; VI, base, 0.091 mm.; VI, filament, 0.225 mm.; total length, 0.951 mm. They are slightly pruinose in each stage.

The material from which these data were taken is mounted on slides and is in the collections of the Bureau of Entomology, bearing Webster number 5151.

The first generation, or stem mothers, is always wingless. All of the following generations differ in color, more especially in the first and second instars. The adult stem mothers, so far as we have been able to learn, never have the darker green dorsal stripe. The antennæ are shorter throughout the different instars, and in the adult also, than in the summer forms.

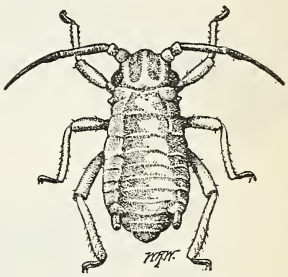

Fig. 12.—The spring grain-aphis: Young, first instar. Enlarged; actual size, 0.75 mm. (Original.)

DESCRIPTION OF THE SUMMER FORMS.

First instar (fig. 12).—Before first molt: General color very pale green, the thorax probably the palest; head pale green with a dusky tinge; eyes brownish black; tip of cornicles black, bases dusky; articulation of femora and tibiæ and distal portion of tibiæ dusky; tarsi black; two apical segments of antennæ black, remaining segments concolorous with head. Antennæ 4-segmented.

Measurements of antennal joints (average from 3 specimens): I, 0.032 mm.; II, 0.033 mm.; III, 0.118 mm.; IV, base, 0.049 mm.; IV, filament, 0.154 mm.; total length, 0.386 mm.

Second instar (fig. 13).—Before second molt: General color slightly paler now; head not dusky; eyes same as in preceding stage; legs with a more greenish tinge now, otherwise same as in previous stage; the two basal joints and the proximal portion of the third joint of antennæ concolorous with head, other portion black. Antennæ 5-jointed.

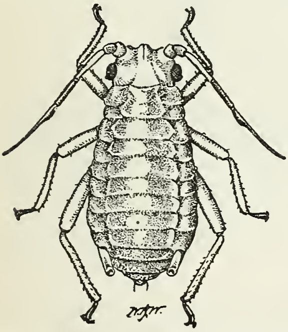

Fig. 13.—The spring grain-aphis: Young, second instar. Enlarged; actual size, 0.922 mm. (Original.)

Measurements of antennal joints (average from 2 specimens): I, 0.041 mm.; II, 0.035 mm.; III, 0.106 mm.; IV, 0.075 mm.; V, base, 0.062 mm.; V, filament, 0.204 mm.; total length, 0.523 mm.

Third instar.—Before third molt: Coloration practically same as in second instar; eyes almost black; bases of cornicles paler than abdomen. Antennæ 5-jointed.

Measurements of antennal joints (average from 2 specimens): I, 0.056 mm.; II, 0.045 mm.; III, 0.172 mm.; IV, 0.099 mm.; V, base, 0.076 mm.; V, filament, 0.259 mm.; total length, 0.707 mm.

Fourth instar.—Before fourth molt: General color deeper green now, very close to apple green; dorsal stripe apparent in this stage at times, eyes of young showing through body wall at this time, head a shade lighter than body and sometimes seeming to be tinged with yellow; eyes brownish black; beak black at tip; legs more of a yellowish green now, the articulation of femora and tibiæ and the distal portion of the tibiæ dusky; tarsi black; the two apical segments of antennæ black, next much lighter, third slightly dusky, and the two basal segments concolorous with head. Antennæ 5-segmented, although sometimes they appear to have 6 segments.

Measurements of antennal joints (average from 2 specimens): I, 0.060 mm.; II, 0.045 mm.; III, 0.272 mm. IV, 0.120 mm.; V, base, 0.086 mm.; V, filament, 0.282 mm.; total length, 0.865 mm.

All of the above stages slightly pruinose.

The following is the description of the adult, summer forms, as given by Mr. Pergande:[1]

Apterous female [fig. 8].—Length 1–1.8 mm.: color yellowish green and slightly pruinose, the median line darker green, the head and prothorax somewhat paler than the rest of the body. Eyes black. Antennæ black, the two basal joints and more or less of the third joint at base yellowish. Legs yellowish, the tibiæ brownish toward the apex, tarsi black. Tail dusky. The general color of the larvæ and pupæ is like that of the apterous female. Wing pads of pupa dusky to black. Antennæ slender and about one-half the length of the body. Nectaries slightly tapering, reaching to or slightly beyond the end of the body. Tail slender, somewhat constricted about the middle, and about two-thirds the length of the nectaries. There is a distinct fleshy tubercle each side of the prothorax and similar tubercles along both sides of the abdomen.

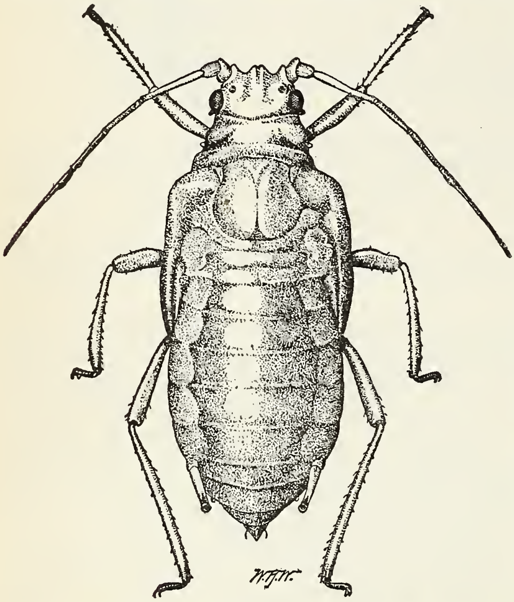

FIG. 14.—The spring grain-aphis: Pupa of winged viviparous female. Enlarged; actual size, 1.875 mm. (Original.)

Migratory female [fig. 7].—Expanse of wings 5–7 mm.; length of body 1.5–2 mm. General coloration of the abdomen as in the apterous forms; head brownish yellow; the eyes brown; antennæ, thoracic lobes, the posterior margin of the scutellum, and the sternal plate black; the two basal joints of the antennæ yellowish green; legs yellow, the femora more or less dusky, the posterior pair darkest; apex of tibiæ and the tarsi black; nectaries and tail yellowish, the latter changing gradually to dusky or black toward the end; wings transparent; costa and subcosta yellow; the stigma somewhat paler, its inner edge and the veins black. Third discoidal vein with but one fork. Antennæ long and slender, reaching nearly to the end of the body, the third joint provided with 3 to 7 sensoria. Nectaries, tail, and lateral tubercles, as in the apterous females.

Besides the sensoria on the third segment of the antennæ mentioned in the above description, there are from 1 to 2 on the fourth, 1 near the apex of fifth, and several, more or less distinct, on the base of the sixth.

Measurements of antennal joints (average from 8 specimens): I, 0.082 mm.; II, 0.059 mm.; III, 0.300 mm.; IV, 0.223 mm.; V, 0.215 mm.; VI, base, 0.110 mm.; VI, filament, 0.395 mm.; total length, 1.384 mm.

To this description we add:

Wingless female (fig. 8).—Coloration for this stage varying from a very pale green with a slight tinge of yellow to a deep apple-green. The dorsal stripe is not always

[1] Bulletin 38, Div. Ent., U. S. Dept. Agr., p. 18, 1902.

present. The size varies greatly in nearly all forms, wingless viviparous females varying from 1.5 mm. to over 2 mm.

Measurements of antennal joints (average for 8 specimens): I, 0.069 mm.; II, 0.045 mm.; III, 0.210 mm.; IV, 0.135 mm.; V, 0.140 mm.; VI, base, 0.089 mm. VI, filament, 0.305 mm.; total length, 0.993 mm.

Pupæ (fig. 14).—Measurements of antennal joints (average from 8 specimens): I, 0.064 mm.; II, 0.056 mm.; III, 0.186 mm.; IV, 0.127 mm.; V, 0.134 mm.; VI, base, 0.090 mm.; VI, filament, 0.270 mm.; total length, 0.927 mm.

Winged viviparous female (fig. 7).—Measurements of antennal joints (average from 8 specimens): I, 0.082 mm.; II, 0.059 mm.; III, 0.300 mm.; IV, 0.223 mm.; V, 0.215 mm.; VI, base, 0.110 mm.; VI, filament, 0.395 mm.; total length, 1.384 mm.

MOLTING.

The time required for molting, from beginning to completion, is 30 minutes. The first indication is restlessness; the antennæ are waved continuously and the legs move jerkily. This period of restlessness continues for 10 minutes, after which the antennæ are allowed to come to rest close down upon the dorsum. A few minutes later the tip of the abdomen will appear transparent and baggy, due to the old skin having slipped backward; the head and eyes are now being freed. It appears that the skin first ruptures in the cephalic region and only splits a part of the length of the dorsum, the insect gradually working its way out from this extremity. After the head, the antennæ are the first to be liberated, then each pair of legs in succession, and after all of the appendages have been freed the insect has still to struggle somewhat to free its abdomen. These observations were made on individuals casting the third or fourth molt.

NUMBER OF MOLTS.

Quite a number of observations were made on the number of molts and the period between the same, it being learned that stem mothers, the summer forms, and the sexes molt 4 times only.

To facilitate careful and accurate observations upon the number of molts, a young wheat plant was potted in a 5-inch flowerpot. A circle of black paper was cut small enough to fit down in the top of the pot. A small hole was then cut in the center and the paper disk was then fitted closely down about the base of the plant. After the paper was in place the space immediately around the plant was filled in with absorbent cotton made black with waterproof ink. Then a young Toxoptera that had just been born was placed on the plant inclosed by a clean lantern globe, with a piece of new cheesecloth firmly secured over the top to prevent the grayish cast skins from being overlooked. Each cast skin was removed as soon as the molt was completed, and a record made so that it could not possibly be counted a second time. All observations recorded in the notes on molting were made in this manner.

During the summer of 1907, at Richmond, Ind., careful observations were made on 7 individuals of the summer forms, and in the fall Mr. R. A. Vickery, of this bureau, made observations on 6 individuals, 3 of which proved to be males and 3 oviparous females. In each case there were 4 molts. In the spring of 1908, 4 stem mothers were found to molt 4 times only. In the spring of 1909 at Lafayette, Ind., 1 stem mother was found to molt 4 times. Later on in the summer, Mr. T. H. Parks, of this bureau, ran a series of experiments with the summer forms and, of the 30 individuals under observation, some of which were winged, he found that all without exception molted 4 times. In the fall of 1910 several additional oviparous females were found to molt 4 times only. This makes a total of over 50 specimens that came under our observation, under conditions that would absolutely preclude error, and there was not a single exception—all molting 4 times.

As it was found that the period between molts varied, experiments were begun in the summer of 1907 at Richmond, Ind., in order to learn how great the variation was when each individual was subjected to the same conditions.[1] This experiment was carried on indoors and all individuals were subjected to the same conditions. Table II will show the variations.

TABLE II.—*Variation in the duration of the different instars in Toxoptera graminum.*

Individual.	From time of birth to first molt.	From first molt to second molt.	From second molt to third molt.	From third molt to fourth molt.
	H. m.	*H. m.*	*H. m.*	*H. m.*
A	38 35	28 29	31 37	39 40
B	40 15	29 15	34 36	34 37
C	50 20	26 40	35 48	40 22
D	45	54	40	64
E	44 30	32 35	36 50	39 37

There is also considerable variation in the time from birth of individuals to the fourth molt and the appearance of the first young, as will be seen from Table III. Individuals in Table III are the same as in Table II, with the addition of "F" and "$1b^3$."

TABLE III.—*Variation in the time from birth of individuals to fourth molt and appearance of first young in Toxoptera graminum.*

Individual.	From time of birth to fourth molt.		From time of birth until first young appear.	
	Hours.	*Days.*	*H. m.*	*Days.*
A	143–144	5.9	144 35	6.02
B	143	5.9	148	6.1
C	153	6.3	164	6.8
D	153	6.3	165	6.8
E	204	8.5	246	10.02
F	195	8.1	205	8.5
$1b^3$	170–175	7.1	[2] 175	7.2

[1] Proc. Ent. Soc. Wash., vol. 10, Nos. 1–2, pp. 11–13, 1908.

[2] Approximate.

BIRTH OF YOUNG.

In the fall of the year 1907 adult individuals of Toxoptera were brought from out of doors into a warm room, placed under a microscope, and observations made on the manner of birth of the young. The embryonic young within the body of the parent are inclosed within a thin, transparent, structureless membrane that corresponds to the vitelline membrane in the true egg. Normally, in warm temperatures, the young Toxoptera frees itself from this enveloping sac during birth. At a temperature of about 60° F. or below, the young are oftentimes dropped before they free themselves from the sac. In this latter case, upon landing upon the surface of the leaf they expand and contract gently until the sac is ruptured at the cephalic extremity and they are freed from their prison.

NUMBER OF GENERATIONS PER YEAR.

During the summer of 1907, at Richmond, Ind., a study of the continuous generations of this species was begun and followed through until December 10, the sexual forms and eggs being secured from bluegrass in the fields in October. With some of the young that hatched from these eggs (stem mothers) March 27 five lines of continuous-generation studies were begun and continued until the appearance of the sexes and eggs in the fall. These eggs were carefully retained and taken to Lafayette, Ind., where, upon their hatching on the first day of the following April, two more lines of continuous-generation studies were begun and continued until ended by the appearance of the sexes and eggs in the fall of 1909, as was the case in 1908.

Toxoptera graminum. *Generation series showing daily reproduction, temperatures, etc. Observations made at Dallas, Tex., 1909, by T. D. Urbahns. Series begun with viviparous and ended with viviparous. No sexes.*

[b=born. —=died or disappeared.]

Date.	Temperature.		First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Twentieth generation.	Twenty-first generation.	Twenty-second generation.	Twenty-third generation.	Twenty-fourth generation.	Twenty-fifth generation.	Twenty-sixth generation.
	Maximum.	Minimum.																										
1909.	°F.	°F.																										
Mar. 31	...	...	b	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Apr. 1	67	42	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	87	37	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	90	44	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	84	56	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	84	65	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	83	86	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	69	48	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	61	50	1	b	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	73	30	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	75	34	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	76	51	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	80	60	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	70	34	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	75	44	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	79	45	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	85	55	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	85	58	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	87	64	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	74	56	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	69	49	2	1	b	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	74	54	1	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	64	51	1	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	65	41	1	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	74	52	1	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	81	62	5	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	75	64	3	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	75	59	1	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	85	63	4	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	98	70	4	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	67	53	2	5	4	b	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
May 1	68	35	0	0	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	68	35	0	1	2	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	87	55	1	4	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

4	93	64	0	3	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	88	66	0	3	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	80	60	0	4	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	87	56	1	2	8	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	89	69	0	—	7	2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	74	57	—	...	6	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	78	41	...	...	—	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	80	44	...	...	...	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	84	61	...	...	...	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	87	64	...	...	...	6	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	86	69	...	...	...	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	85	67	...	...	...	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	89	56	...	...	...	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	93	67	...	...	...	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	77	70	...	...	...	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	87	56	...	...	...	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	84	60	...	...	...	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	84	58	...	...	...	1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	90	62	...	...	...	0	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	91	68	...	...	...	0	6	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24	89	73	...	...	...	0	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	89	65	...	...	...	0	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26	85	60	...	...	...	0	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	95	65	...	...	...	0	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	87	67	...	...	...	0	7	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	89	70	...	...	...	0	7	2	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
30	85	73	...	...	...	0	4	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
31	89	54	...	...	...	0	4	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
June 1	77	66	...	...	...	0	3	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	90	57	...	...	...	0	5	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
3	93	60	...	...	...	0	—	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
4	95	64	...	...	...	0	...	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	98	59	...	...	...	0	...	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6	98	64	...	...	...	0	...	3	3	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	93	67	...	...	...	0	...	3	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
8	96	67	...	...	...	—	...	3	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
9	95	74	...	...	...	...	...	3	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	93	65	...	...	...	...	...	5	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
11	92	70	...	...	...	...	...	4	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
12	92	69	...	...	...	...	...	1	5	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
13	80	66	...	...	...	...	...	1	4	3	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
14	91	64	...	...	...	...	...	0	4	3	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	92	69	...	...	...	...	...	0	4	4	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	96	68	...	...	...	...	...	—	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	99	77	...	...	...	...	...	...	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18	93	69	...	...	...	...	...	...	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
19	95	70	...	...	...	...	...	...	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
20	96	71	...	...	...	...	...	...	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	96	69	...	...	...	...	...	...	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	91	73	...	...	...	...	...	...	—	([1])	5	*b*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23	91	67	...	...	...	...	...	...	...	([1])	([1])	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

[1] No observations on these dates.

Toxoptera graminum. Generation series showing daily reproduction, temperatures, etc. Observations made at Dallas, Tex., 1909, by T. D. Urbahns. Series begun with viviparous and ended with viviparous. No sexes—Continued.

Date.	Temperature. Maximum.	Temperature. Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Twentieth generation.	Twenty-first generation.	Twenty-second generation.	Twenty-third generation.	Twenty-fourth generation.	Twenty-fifth generation.	Twenty-sixth generation.
1909.	°*F.*	°*F.*																										
June 24	92	74								(1)	(1)	0																
25	93	75								(1)	(1)	0																
26	87	75								(1)	(1)	0																
27	96	71								(1)	(1)	0																
28	98	76								(1)	(1)	0																
29	99	75										2	*b*															
30	99	71										—	0															
July 1	99	72											0															
2	88	74											0															
3	100	72											0															
4	100	75											0															
5	96	75											0															
6	97	77											0															
7	99	75											2	*b*														
8	99	77											2	0														
9	102	73											4	0														
10	101	78											2	0														
11	102	78											3	0														
12	100	77											2	0														
13	102	77											2	0														
14	102	77											4	0														
15	98	80											2	0														
16	96	72											0	1	*b*													
17	99	73											0	1	0													
18	96	75											0	1	0													
19	99	73											0	1	0													
20	99	71											0	2	0													
21	98	71											0	0	0													
22	97	76											0	2	0													
23	97	77											0	2	2	*b*												
24	99	75											0	0	3	0												
25	96	76											0	—	7	0												
26	97	76											0		3	0												
27	97	78											0		4	0												
28													—		3	0												
29	99	77													2	1												

30	101	75	...	...	...	...	...	...	...	...	...	...	...	...	—	2	...	...	...	...	...	...	...	...	...	...	...	...
31	102	80	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...	...
Aug. 1	93	75	...	...	...	...	...	...	...	...	...	...	...	...	...	1	b	...	...	...	...	...	...	...	...	...	...	...
2	100	71	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...	...	...
3	103	72	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	...	...	...	...
4	105	74	...	...	...	...	...	...	...	...	...	...	...	...	...	—	0	...	...	...	...	...	...	...	...	...	...	...
5	102	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
6	104	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
7	99	71	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
8	86	72	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
9	93	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
10	97	74	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
11	97	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
12	98	74	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
13	84	72	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...	...
14	97	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	b	...	...	...	...	...	...	...	...	...	...
15	100	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...	...
16	105	77	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	...	...	...	...	...	...	...	...	...	...
17	110	72	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	...	...	...	...	...	...	...	...	...	...
18	114	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...	...
19	105	76	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	0	...	...	...	...	...	...	...	...	...	...
20	96	80	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...
21	99	70	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...
22	100	67	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	...	...	...	...	...	...
23	100	65	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	b	...	...	...	...	...	...	...	...	...
24	84	70	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...
25	95	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	...	...	...	...	...	...	...	...	...
26	99	71	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...
27	100	69	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...
28	100	72	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	0	...	...	...	...	...	...	...	...	...
29	99	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	1	...	...	...	...	...	...	...	...	...
30	99	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...
31	101	74	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...	...
Sept. 1	99	75	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	4	b	...	...	...	...	...	...	...	...
2	100	70	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	3	0	...	...	...	...	...	...	...	...
3	98	74	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	0	...	...	...	...	...	...	...	...
4	98	72	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	2	0	...	...	...	...	...	...	...	...
5	101	72	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	0	...	...	...	...	...	...	...	...
6	96	74	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	3	0	...	...	...	...	...	...	...	...
7	99	69	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	3	1	...	...	...	...	...	...	...	...
8	99	69	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	1	...	...	...	...	...	...	...	...
9	100	71	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	1	b	...	...	...	...	...	...	...
10	103	68	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	1	0	...	...	...	...	...	...	...
11	102	73	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	0	2	0	...	...	...	...	...	...	...
12	100	74	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	—	3	0	...	...	...	...	...	...	...
13	97	76	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	2	0	...	...	...	...	...	...	...
14	84	67	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	1	0	...	...	...	...	...	...	...
15	90	61	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	1	0	...	...	...	...	...	...	...
16	91	67	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	2	0	...	...	...	...	...	...	...
17	94	54	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	...	2	2	b	...	...	...	...	...	...

[1] No observations on these dates.

Toxoptera graminum. *Generation series showing daily reproduction, temperatures, etc. Observations made at Dallas, Tex., 1909, by T. D. Urbahns. Series begun with viviparous and ended with viviparous. No sexes*—Continued.

Date.	Temperature. Maximum.	Temperature. Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Eighteenth generation.	Nineteenth generation.	Twentieth generation.	Twenty-first generation.	Twenty-second generation.	Twenty-third generation.	Twenty-fourth generation.	Twenty-fifth generation.	Twenty-sixth generation.
1909.	°F.	°F.																										
Sept. 18	95	52	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3	0	...	...	...	...	...	...
19	97	61	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	0	...	...	...	...	...	...
20	97	65	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	0	...	...	...	...	...	...
21	96	66	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	4	0	...	...	...	...	...	...
22	96	77	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	4	0	...	...	...	...	...	...
23	84	58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	0	...	...	...	...	...	...
24	85	49	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	1	*b*	...	...	...	...	...
25	85	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	5	2	0	...	...	...	...	...
26	85	53	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	3	0	...	...	...	...	...
27	79	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	2	3	0	...	...	...	...	...
28	82	41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	3	0	...	...	...	...	...
29	89	41	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	0	...	...	...	...	...
30	92	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	3	0	...	...	...	...	...
Oct 1	92	49	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	3	0	...	...	...	...	...
2	92	49	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	—	3	0	...	...	...	...	...
3	94	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	...	...	...	...	...
4	92	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	0	...	...	...	...	...
5	92	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	4	*b*	...	...	...	...
6	94	54	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	3	0	...	...	...	...
7	91	57	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	4	0	...	...	...	...
8	72	63	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	4	0	...	...	...	...
9	69	51	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	0	...	...	...	...
10	79	39	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3	0	...	...	...	...
11	64	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	0	...	...	...	...
12	66	42	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	0	...	...	...	...
13	84	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	1	0	...	...	...	...
14	96	64	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	3	2	*b*	...	...	...
15	89	53	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	5	2	0	...	...	...
16	86	63	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3	5	0	...	...	...
17	87	69	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	3	4	0	...	...	...
18	80	65	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	4	4	0	...	...	...
19	63	61	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	3	0	...	...	...
20	77	47	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	2	0	...	...	...
21	87	58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	2	3	0	...	...	...
22	87	58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	2	4	0	...	...	...

23	81	52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	2	2	0	.....	.....	.....
24	69	40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	1	2	1	*b*	.....	.....
25	77	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	2	2	0	.....	.....
26	80	38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	0	3	3	0	.....	.....
27	86	47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	—	3	2	0	.....	.....
28	85	54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	3	2	0	.....	.....
29	81	49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	4	3	0	.....	.....
30	82	57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	3	4	0	.....	.....
31	83	67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	1	3	0	.....	.....
Nov. 1	80	44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	1	4	0	.....	.....
2	83	43	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	1	3	0	.....	.....
3	86	42	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	0	1	.....	.....
4	83	44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	1	4	4	*b*	.....
5	80	57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	6	6	0	.....
6	82	63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	6	7	0	.....
7	82	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	4	4	0	.....
8	65	59	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	3	3	0	.....
9	73	44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	3	3	0	.....
10	78	57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	3	4	0	.....
11	82	68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	4	5	0	.....
12	77	67	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	3	5	3	*b*
13	77	66	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	5	5	7	0
14	58	43	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	0	2	4	3	0
15	71	47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	—	.....	—	—	—	—	—

Mr. T. D. Urbahns, of this bureau, carried on a series of check experiments at Dallas, Tex., in 1909, starting in March and ending in the fall. (See table, pp. 64–69.) As will be observed, and for reasons explained farther on, he did not obtain the sexes. By these experiments the maximum number of generations was secured as described under rearing methods (p. 51). The maximum number of generations in 1908 among the five series of continuous generations was 21 and, as shown below, occurred in series I of first-born; the minimum being 6 in series FF of the series of last-born. The complete series are as follows: Series B, maximum (from first-born), 20 generations; series BB, minimum (from last-born), 9 generations; series C, maximum (from first-born), 18 generations; series CC minimum (from last-born), 8 generations; series F, maximum (from first-born), 16 generations; series FF, minimum (from last-born), 6 generations; series G, maximum (from first-born), 19 generations; series GG, minimum (from last-born), 9 generations; series I, maximum (from first-born), 21 generations; series II, minimum (from last-born), 10 generations. If all of these be added, we will find the average to be 13.6 generations. This will represent the approximate number of generations for the year. In 1909 there were two series reared, A and B, both resulting the same. Series A, maximum (from first-born), 18 generations; series AA, minimum (from last-born), 7 generations; series B, maximum (from first-born), 18 generations; series BB, minimum (from last-born), 7 generations. The average for these two lines would give 12.5 generations, a little lower average than at Richmond, Ind.

Mr. Urbahns carried out one series of first-born generation experiments at Dallas, Tex., in 1909, from which he obtained only the maximum number of generations. He began March 31 and finished November 3. In this time he reared through 25 generations but did not ascertain the sexes, neither was he successful in finding them in the fields.

It appears that the species will vary in the number of generations produced from individuals hatched the same day, and from the offspring kept under the same conditions throughout the year. This will readily be understood when the amount of individual variation in molting is considered.

AGE AT WHICH FEMALES BEGIN REPRODUCING.

The age at which females begin reproducing varies greatly between spring and summer and between fall and summer; as between spring and fall the age is very much the same. At Richmond and La Fayette, Ind., Toxoptera begins reproducing at from 5.9 to 16 days between the middle of May and latter part of September. From the time of hatching until the middle of May the period is from 20 to 27 days;

from the latter part of September to and including November the period varies from 12 to 53 days. A case occurred in the autumn of 1907 where it required 53 days for a single individual to reach maturity. This individual continued to live up to the 10th of December, when all experiments were closed. The average period from birth to reproduction for the summer months, early spring, and early fall is 9, 22, and 19 days respectively. The average for the entire year, or for the period in which the species breeds, parthenogenetically, for Richmond and La Fayette, Ind., is 16.6 days. In arriving at these averages, all individuals of the generation experiments for 1907, 1908, and 1909 were considered.

Mr. Urbahns found that at Dallas, Tex., the period varied from 7 to 12 days from birth to reproduction, from March to the middle of May; from 6 to 14 days from the middle of May until the last week in September, and from 9 to 11 days from the last week of September to November 3. The average number of days from birth to reproduction for each of these periods is 9.6, 7.4, and 9.7 days, respectively. Mr. Urbahns reared a number through December up to the middle of January. During this period the time between birth and reproduction was very much greater, varying from 18 to 25 days, with an average of 20.5 days. The average, beginning with April and continuing until November 3, is 8.9 days. From the foregoing data it will be seen that under favorable conditions Toxoptera breeds much more rapidly in the South than in the North. All of the reproduction experiments upon which these figures are based were carried on out of doors, but the insects were protected from the hot rays of the sun in the summer.

REPRODUCTIVE PERIOD.

The period of reproduction covers a greater average length of time in spring and fall than during summer, being greatest in the spring, even though the maximum period of reproduction for a single female is practically the same for the three periods.

In computing these averages each individual of all the lines of continuous generations was considered, even though they reproduced for a single day only and then died or disappeared from some unknown cause; hence the averages are lower than they would be had these latter individuals not been considered. From this data it will be seen that both the maximum and the average periods are the greatest in the North, where the insect is able to breed continuously in unprotected places throughout the summer.

At Richmond and La Fayette, Ind., the maximum period of reproduction for individuals born from March to the middle of June is 45 days, the minimum 1 day, and the average 18 days; the maximum for individuals born from the middle of June to the middle of August

is 43 days, the minimum 1 day, the average being 12.6 days; the maximum for those born after the middle of August is 45 days and the minumum 5 days, the average being 24 days, while the average for the entire season is 16 days.

In Texas the difference between summer, spring, and fall is still more marked, December and January being about the same as the summer months. Mr. Urbahns found that during December and January the maximum reproduction period was 19 days and the minimum 2 days, the average being 8 days; during April and May the maximum was 30 days and the minimum 4 days, the average being 16.8 days; during June, July, and August the maximum was 16 days and the minimum 4 days, the average being 8.4 days; during September, October, and November the maximum was 28 days and the minimum 3 days, the average being 17 days. The average for the entire season was 13.9 days.

LONGEVITY.

At Richmond and La Fayette, Ind., Toxoptera lives for a much longer period in the spring and fall than in the summer. In fact, in the summer it often survives a shorter time than is required for it to reach maturity in the spring and fall.

Those born from the latter part of March to the last week in May live from 15 to 78 days, the average being 43 days; those born from the first week in June to the middle of August live from 9 to 57 days, the average being 24 days; those born from the middle of August on through September live from 12 to 75 days, the average thus being 40 days. The average length of life for the whole viviparous breeding season is 35 days. These averages are not made up from the maximum and minimum alone but every individual in the line of first-born of the continuous generation experiments is considered.

Mr. Urbahns found that in Texas the spring grain-aphis lived much longer in spring and fall than in summer. In fact, in the summer it was difficult to keep it alive at all, it being necessary to keep the cages in the shade.[1] He also carried on some reproduction experiments in December and January, and in these two months found that it lived from 25 to 39 days, averaging 34 days. In April and May it lived from 13 to 47 days, averaging 35 days; in June, July, and August it lived from 10 to 30 days, averaging 17 days; in September, October, and part of November it lived from 11 to 56 days, averaging 28 days; the average for the season (from March to November) was thus 26 days.

In making up these averages only whole numbers are used, fractional parts of a day not being considered. Also, all individuals upon which we had complete observations were considered.

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[1] Ante, p. 47.

FECUNDITY OF VIVIPAROUS FEMALE.

The average person, unfamiliar with the habits of the Aphididæ, would scarcely think it possible for such small creatures to become sufficiently numerous to devastate vast areas of grainfields, destroying millions of dollars' worth of property within the space of a few weeks. When one becomes familiar with their powers of reproduction, however, the problem seems very simple.

Prof. Huxley [1] states that the tenth generation alone of a single rose aphis, were all of its members to survive the perils to which they are exposed, would contain more substance than 500,000,000 stout men. Buckton,[2] commenting on Prof. Huxley's figures, states that he much underestimates the real quantity of animal matter capable of elaboration from a single aphis in a year, and goes on to say:

Basing the calculation, for simplicity, upon the supposition that every aphis lives twenty days, and that at the expiration of that period each aphis shall have produced twenty young and no more, then at the expiration of three hundred days *only*, the living individuals would be represented by the following figures:

Aphides.	Days.	Aphides.	
1 produces in	20	20	= a
a produces in	$40=20^2$	400	= *b*
b produces in	$100=20^5$	3, 200, 000	= *c*
c produces in	$200=20^{10}$	10, 240, 000, 000, 000	= *d*
d produces in	$300=20^{15}$	=32, 768, 000, 000, 000, 000, 000	= e

Again, if 1,000 aphides weigh 1 grain, and
1 man weighs 2,000,000 grains
1 man weighs 2,000,000,000 aphides.

$\therefore \frac{E}{2,000,000,000}=1,638,400,000$ men; equal, perhaps, to the population of China sevenfold.

To quote further:

But a mathematical friend remarks that this calculation even does not express the real rate of increase, since it supposes the progeny of the first aphis to be produced *at once*, and not to commence producing until the expiration of the first twenty days. To this same friend I am indebted for the annexed calculation.

If we suppose the progeny of the first aphis to equal 20 in twenty days, and this progeny to begin producing when five days old 20 young, each of which again on attaining the age of five days begins the propagation of 20 young, and completes also that number in 20 days:

Then at the end of 20 days from the commencement of first aphis production there would be direct issue .... $= 20a$

At the end of fifth day, progeny *a* begin to produce, which at the end of first 20 days will altogether equal 15+14+13+12, &c.+2+1 .... $=120b$

At the end of tenth day, progeny *b* begin to produce, which at the end of the first 20 days will altogether equal 10+9+8, &c. +2+1 .... $= 55c$

At the end of the fifteenth day, progeny *c* begin to produce, which at the end of the first 20 days will altogether equal 5+4+3+2+1 .... $= 15d$

Total at the end of 20 days equals $a+b+c+d$ .... $=210$

The amount, therefore, at the end of 300 days (or 20×15) would not be less than the fifteenth power of 210, which is almost impossible to express in figures. There would be room in the world for nothing else but aphides.

[1] Trans. Linn. Soc., vol. 22, p. 215 (part 3, 1858). [2] Monograph of British Aphides, vol. 1, p. 80.

Toxoptera, in all probability, would not fall far behind these figures and the number might even be greater. Be that as it may, the illustration will suffice to show us that Toxoptera, with such remarkable powers of reproduction, could easily overrun the whole country if not checked in some manner.

At Richmond and La Fayette, Ind., the maximum number of young produced in 24 hours was 8 in June, July, and August. The maximum number of young produced by any individual was 93, in the month of July. In Texas Mr. Urbahns found the maximum in 24 hours to be 10 young in May, and the total number of young for one individual reached as high as 84 during the same month.

At Richmond and La Fayette, Ind., considering the progeny from only the individuals of the line of first-born generations, the average number of young for the summer falls below either spring or fall, the spring being in the lead. When both the individuals from the line of first and last born generations are considered, those of the fall average less than those of the spring or summer. In 1908 the evidence was in favor of the line of first-born generations as being more prolific than the individuals of the line of last born. In 1909 the line of last-born generations held its own, especially in the spring and summer, falling behind slightly in the fall. In fact, in each line of generation experiments, the last born fall behind in average number of young in the autumn. Also, if an average be taken of the first and last born separately, the latter will fall behind. Considering each individual of both lines in all generations, both first and last together, the results are as follows: The maximum number of young produced by those born from March to the middle of June is 69, the average number for each individual for this period being 30.3; the maximum for those born from the middle of June until the middle of August is 93 young, the average number for each individual being 25.3; the maximum for those born after the middle of August is 66 young, the average for each individual being 24.

The average number of young, including every individual under observation, whether connected with the generation experiments or otherwise, for the entire viviparous breeding season, of the years 1907, 1908, and 1909, beginning the last week in March and continuing until November, both inclusive, is 28.2; there being 216 individuals used to obtain this average.

In the generation experiments were a number of individuals that produced from 1 to 10 young and then disappeared, apparently not dying from natural causes. All of these were included, however, in arriving at the final average, as any average obtained by excluding one or more individuals from any cause whatever would be more or less arbitrary, since in nature the mortality, in all probability, would be much greater. All of the rearings were carried on out of doors,

and as the individuals were isolated and protected as much as possible from natural enemies it is probably safe to say that this average is as high as would obtain in the open fields, where they are convenient prey for their enemies.

Mr. Urbahns found that in Texas the average number of young produced in the spring and fall was much greater than in the summer. The averages for December and January agree very well with those of the summer period.

The maximum number of young produced by a single individual, under observation by Mr. Urbahns, that began reproducing in December and January was 29, the average for this period being 17. 1; the maximum for those that began reproducing in April and May was 84, the average being 58.5 young; the maximum for those that began reproducing in June, July, and August was 39, the average being 17.2 young; the maximum for those individuals that began reproducing after August was 73; the average for the period from March to November is 39.7; the average for the entire number of individuals upon which Mr. Urbahns made observations during 1909, including the rearings during December and January, is 34 young. As will be observed, this is considerably above the average for Indiana.

From the foregoing data it will be seen that the spring, in both the North and the South, is the most favorable period for reproduction; in the North the summer period ranks next, the fall coming last, while in the South the summer is so hot that the aphidids can scarcely live at all, the fall ranking next to spring for productiveness.

FECUNDITY OF WINGLESS VERSUS WINGED FEMALES.

In 1890 the senior author gathered from his observations that the wingless forms were more prolific than the winged. In 1907 the junior author came to the same conclusion. In 1909 Mr. Urbahns, in Texas, observed that the winged forms did not appear to be so prolific as the wingless forms. During the summer of 1909, at La Fayette, Ind., the junior author carried on some experiments with a view of learning, if possible, something definite in regard to this matter. For this purpose 8 nymphs with wing pads and 8 larvæ in the fourth stage were selected and each placed in a separate cage, each cage being placed under the same conditions. This experiment began on the 30th of August and all individuals became adult about the same time. The maximum number of young produced by a single winged individual was 44 and the minimum was 10; the maximum number of young produced by a single wingless individual was 61 and the minimum was 4. The total number of young produced by the 8 winged individuals was 224, or an average of 28 young for each individual; the total for the 8 wingless individuals was 274, or

an average of 34.25 young to each individual. While too small a number of individuals was taken to make the result conclusive, it plainly indicates that fecundity is greatest among the wingless individuals.

AVERAGE NUMBER OF YOUNG PRODUCED DAILY.

By "the average daily number of young produced" is meant the daily average for the reproductive period only of each individual. At Richmond and La Fayette, Ind., the average number of young produced daily for those born from March to the middle of June is 1.9; the daily average for those born from the middle of June to the middle of August is 1.7; the daily average for those born after the middle of August is 1.2. These figures, of course, include only those individuals in the generation experiments. The average number of young produced daily for the entire year is 1.6. The final average remains the same when all individuals are considered, irrespective of generation experiments.

From the above it will be seen that the daily average is greatest in the spring, the summer coming next, and the fall last. This corresponds also to the average total number of young for each individual for these periods.

Mr. Urbahns found that the average number of young produced daily at Dallas, Tex., for those individuals that began reproducing during December and January was 1.5; the daily average for those that began reproducing during April and May was 3.4; the average for those that began reproducing during June, July, and August was 2.1; the average for those born after August was 2.5. These averages will be seen to agree proportionately with the average number of young produced by a single individual during these periods, with the exception of the daily average for December and January, which is considerably lower. The average daily number of young for the entire breeding season for which Mr. Urbahns has any data is 2.

From the above data it will be seen that the average daily number of young for Texas is far above the average for Indiana. This can probably be accounted for from the fact that the reproductive period is much longer in the North and the young are distributed over a longer period. Also the average number of young for each individual is greater in the South.

SEXUAL FORMS.

The first young of the sexes in Indiana are apparently born the last week in September, the first adults oftentimes appearing as early as the first week of October. The adults can be found from this time on until December, or until they are killed off by extreme cold.

The males can easily be distinguished by their small size. The oviparous females (fig. 9) can be readily distinguished without a hand

lens by the yellowish areas over the abdomen, due to the fact that the eggs show through the body walls; also, if the males have not been with them, by the manner in which they rest upon the plant, the body being held at an angle of about 45° to the leaf upon which they rest. In assuming this position they hold to the plant only with the two first pairs of legs. Only unmated females rest upon the plant in this manner. The sexes may mate once or many times, although one mating is apparently sufficient to produce fertile eggs.

One agamic female may produce all agamic individuals, a combination of agamic males and oviparous females, or only true females and males. When only the latter, it seems that the females far outnumber the males.

Mr. C. N. Ainslie, in 1908, in Washington, D. C., records a very singular phenomenon. On April 4 of that year he observed males, oviparous females, and eggs of Toxoptera in his cages in the office. A number of eggs were obtained, but none of them would hatch. The source of this material, however, is somewhat obscure. Mr. Kelly had sent in material from Leavenworth, Kans., previous to these finds and this was kept breeding in the office, together with material collected locally. The junior author also found an adult male in his rearing cages in the insectary at Washington during April, 1911. This apparently developed from material that had been kept breeding all winter.

DESCRIPTIONS.

Since in the earlier stages the young can not be distinguished from those of the summer forms, it is unnecessary to go into detail with reference to them. The males may probably be identified in the third instar by their small size; they are much smaller and the abdomen more pointed, posteriorly, than the summer forms of this stage that later will become winged. Those young that will develop into oviparous females can not be determined with any degree of accuracy until the fourth instar. They are usually a little paler in color, and, instead of embryos, light yellowish ova can be seen, with a hand lens, developing within the body (see fig. 9). The description of the male and female first appeared in the Canadian Entomologist, in an article on "Sexual Forms of *Toxoptera graminum*, Rond," by Prof. F. L. Washburn.[1] His description is as follows:

Oviparous female.—Length, 2–2.25 mm.; color, yellowish green, median line of abdomen darker green; head and prothorax somewhat paler than the rest of the body. Eyes black; antennæ black, except the two basal joints, and the basal half of the third, which are the same color as the head. Legs yellowish, tibia brownish toward the apex, tarsi black; cornicles greenish, their apex black; cauda greenish. Antennæ slender, hardly one-half the length of the body, no circular sensoria. Cornicles slightly tapering, not reaching to the end of the body. Cauda slender, somewhat

[1] Can. Ent., vol. 40, No. 2, February, 1908.

constricted above the middle, about two-thirds the length of the cornicles. Tibia of hind leg (fig. 10) swollen and thickly covered with sensoria-like swellings. Lateral tubercles small and single.

Winged male.—Expanse of wings about 4.5 mm.; length of body about 1.3 mm. General coloration of the abdomen yellowish green; head brownish-yellow; eyes black; antennæ black, except the two basal joints and the proximal half of the third, which are yellowish green. Legs yellow, the femora more or less dusky, the posterior pair darkest; apex of the tibia and tarsi black; cornicles yellowish, with black apex; cauda yellowish. Wings, costa and subcosta yellow; stigma paler, the inner edge of the stigma and the veins black. Antennæ long and slender, reaching to or a little beyond the end of the body; third joint with about twenty circular sensoria; fourth with about eighteen; fifth with about nine. Cauda slender, somewhat constricted about the middle, as long as the cornicles. Lateral tubercles small and single.

To this description we add the following:

Oviparous female.—Measurements of antennal joints (average from eight individuals): I, 0.067 mm.; II, 0.050 mm.; III, 0.229 mm.; IV, 0.166 mm.; V, 0.172 mm.; VI, base 0.095 mm.; VI, filament, 0.369 mm.; total length, 1.148 mm.

Male (average from six individuals) (fig. 6): I,0.064 mm.; II, 0.051 mm.; III, 0.361 mm.; IV, 0.243 mm.; V, 0.242 mm.; VI, base, 0.107 mm.; VI, filament, 0.407 mm.; total length, 1.475 mm.

We find also that the coloration of the oviparous female varies considerably from almost a clay-yellow with a faint tinge of green to a deep green. Individuals are somewhat pruinose also. As they become older the legs and bases of the antennæ get darker; each margin of the base of the cauda becomes quite dark.

The abdomen of the male varies somewhat in color from deep apple-green to pale green; the thoracic plates, dorsally and ventrally, are of an olive color.

MOLTING.

As stated on page 62 Mr. Vickery, of this bureau, conducted some experiments at Richmond, Ind., in 1908, to ascertain the number of molts for the sexes. He selected 6 individuals just as they were born and isolated each in cages as heretofore described. Three proved to be males and 3 oviparous females, all of which molted 4 times. Also, at La Fayette, Ind., in 1909, the junior author found that the oviparous forms molted 4 times.

OVIPAROUS DEVELOPMENT.

AGE AT WHICH FEMALES BEGIN OVIPOSITION.

The age at which females begin depositing eggs varies greatly according to weather conditions. From 11 to 41 days are required for them to become adult. If they happen to be born the last week in September or the first week in October the chances are that they will become adult within about 11 days. If they have the misfortune to be born the last week in October or during November it may take them over a month to reach maturity; perhaps they would

not reach maturity at all in case of an early winter. After reaching maturity they will, when accompanied by the male, begin ovipositing in from 3 to 9 days; if the weather is warm, in from 3 to 4 days. The period, then, from birth to oviposition varies from about 14 to 44 or 45 days. Females will, in rare instances only, oviposit without first having been with the male. They will live unfertilized from 31 to 71 days without ovipositing, the abdomen becoming very much distended, and, upon dissection, 6 or more fully developed eggs may be found. In one case a female deposited 2 eggs without having been with a male, but no development occurred within the egg and it shriveled and dried up within a few days. When nearly through ovipositing the female becomes shrunken and misshapen, as shown in figure 15. (Compare with fig. 9.)

PLACE OF OVIPOSITION.

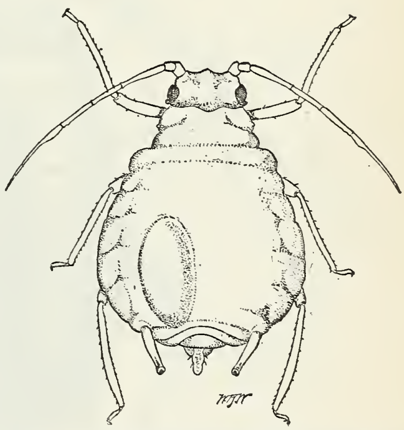

FIG. 15.—The spring grain-aphis: Shrunken and nearly spent oviparous female. Enlarged. (Original.)

Throughout the North it appears that bluegrass (*Poa pratensis*) is the most common host plant of Toxoptera, though it occasionally, on account of favorable weather conditions or the scarcity of natural enemies, becomes excessively abundant there and escapes to the grains in destructive numbers. Consequently it appears that the sexes normally occur on bluegrass. It is also true that they will be better protected from the extremes of temperature among tall, rank growing bluegrass than they would be on the grains in open, bleak fields.

In only a very few instances have we been able to find the sexes upon the growing grains in the fields. It is an easy matter, however, to locate them upon bluegrass in waste places. They apparently prefer dead or dying leaves and crawl out near the tip of the leaf, where it has begun to fold, and here deposit their eggs. (See fig. 11.) Several old females have been found at the same time within the curl of a leaf, and as many as 14 eggs have been found upon a single leaf.

PERIOD OF OVIPOSITION.

Here again, as in the case of viviparous development, varying temperatures are probably the main factor in determining the length of the productive period. Eggs continue to develop within the bodies of the females, apparently, as the embryos do within the

bodies of the viviparous individuals, so long as warm weather continues or until the females become old and die a natural death. The viviparous forms appear to be as susceptible to extreme cold as are the oviparous individuals.

From the 14 experiments that were conducted to determine the period of oviposition it was found that it varied from 3 to about 25 days. If, after becoming adult, the female be kept for a week or more and then placed with the male it appears that the reproductive period is shortened.

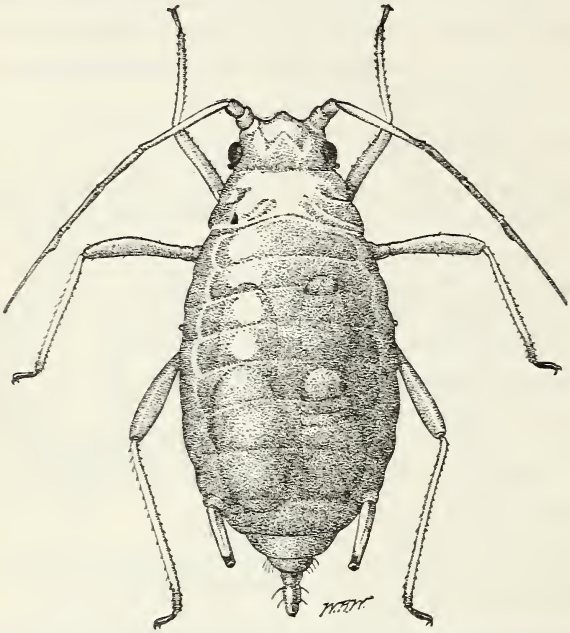

FIG. 16.—The spring grain-aphis: Aberrant female with eggs and embryos in abdomen, showing through the body wall. Enlarged. (Original.)

LENGTH OF LIFE OF THE SEXES.

The males reach maturity, it seems, as quickly as the oviparous females, but their lives are much shorter. The males live from 8 to 10 days after becoming adult.

The length of life of the oviparous females depends principally upon two factors, namely, weather conditions and the presence of the male. Under favorable weather conditions, and in the presence of the male, they will live from 31 to 68 days. If the male is not present they will sometimes live as long as 88 days. Under these circumstances they rarely deposit eggs, only one instance, as previously cited, having come under our observation where they did oviposit and then the eggs were not fertile. Their abdomens become greatly distended with eggs, and upon being dissected, as many as six or more full-sized eggs may be found.

FECUNDITY OF OVIPAROUS FORMS.

The oviparous forms are far less prolific than the viviparous. They produce, under favorable circumstances, from 1 to 10 eggs, or an average of 5.4 eggs per individual. This average was made up from observations on 27 individuals.

ABERRANT INDIVIDUALS.

During our studies of Toxoptera we have found some rather interesting abnormalities. In December, 1907,[1] while dissecting some individuals in the laboratory, two were found that contained both living embryos and true eggs. In April, 1908, Mr. C. N. Ainslie found the same phenomenon occurring in individuals here in Washington. These latter resembled the wingless viviparous forms externally (see fig. 16). Mr. S. J. Hunter, in "The Green Bug and Its Enemies," finds, besides this form, what he terms "winged intermediate females, resembling the winged agamic females in antennal characteristics." Other writers mention the same phenomenon as occurring among other species of plant-lice, and no doubt these abnormalities occur much oftener than any of us are aware. At present, however, there appears to be no satisfactory explanation of such occurrences.

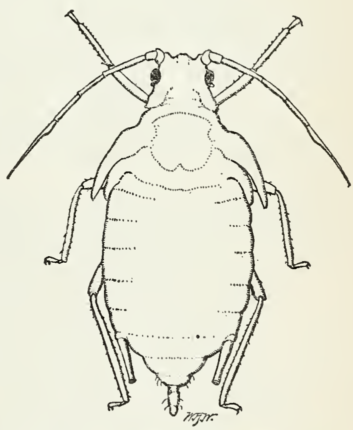

FIG. 17.—The spring grain-aphis: Aberrant female pupa which produced young. Enlarged. (Original.)

One single instance came under our observation where a puparium produced 6 young and then died. The cauda of this individual resembled that of an adult insect and the wing-pads were aborted, the abdomen being much broader than that of the normal pupa. (See fig. 17.)

INFLUENCE OF WINDS ON DIFFUSION.

By referring to the maps (fig. 5) showing the area covered by the different outbreaks of Toxoptera in the United States, west of the Mississippi River, it will be observed that they have all had their origin in central Texas, with a single exception, extending broadly to the north and northeast. This was especially true of two most destructive invasions of 1890 and 1907, and was also implied by that of 1901, the case of 1903 having been too incipient. This strongly indicates

[1] Proc. Ent. Soc. Wash., vol. 10, pp. 11-13, January, 1908.

the presence, during each extended invasion, of some important influence that shapes, to a marked degree, the course of these invasions across the country northward and northeastward from the point of their origin in the South. Probably this is due primarily to the direction of the winds during the months between January and June.

The degree of influence exerted by the winds in the diffusion of Toxoptera is, however, dependent upon several other factors. In the first place, with wingless individuals alone present, it is clear that no amount of wind of whatever velocity would distribute the species to any considerable degree. Therefore, it is necessary to understand the vital forces that regulate the abundance of winged individuals, which, at the critical period, would probably be almost without exception viviparous females. Field observations have shown, not only among this but among other species of aphidids, that a curtailing of the food supply is a most potent influence in producing the aerial form. Not only has it been observed with Toxoptera that as the food plants lose their vigor, affording less nutrition, the winged individuals become more and more abundant in the fields, but both Mr. Phillips and Mr. Urbahns have been able, by regulating the food supply, to produce these winged individuals, artificially at will, in their rearing cages. In the case of *Macrosiphum granaria* Buckt., it has always been noticed that though the heads of wheat be literally swarming with wingless females and young, these young do not perish as the food supply becomes exhausted on account of the ripening of the grain, but develop into winged adults which fly away, leaving only the cast larval and pupal skins on the ripening wheat heads. Therefore, so long as there is an abundant supply of vigorous young grain the percentage of winged adults appearing will be comparatively few. The condition of the food supply, then, is a prime factor in the diffusion of Toxoptera, except when greatly decimated in numbers from excessive parasitism.

If the temperature be below the point of activity for the species, it is very clear that the velocity of the wind would have no effect whatever upon the diffusion of the insect. The conditions necessary, then, for the wind to exert its greatest influence will be a decreasing food supply for the insect under a temperature considerably above that actually necessary for its activity, with numbers not seriously reduced by parasites; under these conditions, many species of aphidids are known to be carried about in immense numbers by the winds.

White, in his Natural History of Selborne [1] has this reference to a migration of small aphidids.

> As we have remarked above that insects are often conveyed from one country to another in a very unaccountable manner, I shall here mention an emigration of small Aphides, which was observed in the village of Selborne no longer ago than August 1, 1785.

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[1] Natural History and Antiquities of Selborne. By the Rev. Gilbert White, M. A., London, 1836, pp. 365–366.

At about three o'clock in the afternoon of that day, which was very hot, the people of this village were surprised by a shower of Aphides, or smother-flies, which fell in these parts. Those that were walking in the street at that juncture found themselves covered with these insects, which settled also on the hedges and gardens, blackening all the vegetables where they alighted. My annuals were discoloured with them, and the stalks of a bed of onions were quite coated over for six days after. These armies were then, no doubt, in a state of emigration, and shifting their quarters; and might have come, as far as we know, from the great hop plantations of Kent or Sussex, the wind being all that day in the easterly quarter. They were observed at the same time in great clouds about Farnham, and all along the vale from Farnham to Alton.

Prof. Karl Sajo calls attention to the fact that many aphidids creep to the crowns of the plant which they infest and then drop themselves at the proper moment into the boiling current of the storm.[1] In the studies made of Toxoptera many instances of this nature have been observed. It will be recalled that *Toxoptera graminum* appeared in swarms about Parma, Italy, in 1847 and again in 1852. The notes of Mr. C. N. Ainslie, made on Toxoptera in Oklahoma and Kansas, contain very many similar interesting records.

At Kingfisher, Okla., under date of March 27, 1907, Mr. Ainslie makes this record.

Toxoptera flying to-day by the million. The air was full of the migrants, and farmers who drove to town were covered on the windward side to their annoyance. The aphides seem for the most part to fly low, but the wind hurried them at such a rapid rate that they might easily have been invisible when higher in the air.

The following day his field notes contained these significant statements: "Large numbers of Toxoptera on the wing to-day, always moving north," and as those who have studied the species will understand, the most interesting statement was that "A heavy thunder shower passed by on the north last night, 30 miles away, and a few drops fell here." In the same locality, under date of April 3, he states that winged individuals of Toxoptera were taking to wing freely, for he had observed many leaving the blades in the fields and taking flight. Again, under date of April 6, "The air is full of flying Toxoptera to-day, going northeast with a light breeze. They do not fly high, from 2 to 15 feet." (The temperature at Wichita, 30 miles north, was from 42° to 57° F.) At Wellington, Kans., April 24 (with Wichita temperature 45° to 81° F.), he found Toxoptera flying by the million and farmers driving to town had to shelter their eyes from the swarm. On April 29, he records these observations:

Yesterday afternoon was warm for awhile (41° to 63° F. at Wichita), light northwest breeze. Toxoptera took wing in immense numbers for 15 or 20 minutes, drifting southwest, but soon saw their mistake and the air cleared. This is the only instance seen by me when these aphides failed to fly north. The wind did not carry them far this time. A Sunday ball game was in progress when they flew, and I was told that the myriads of aphides interfered with the game; it was like trying to play in a snowstorm.

[1] The Wanderings of Insects. Prometheus, vol. 1, by Prof. Karl Sajo.

Under date of May 17, 1907, also at Wellington, Kans., Mr. Ainslie made an interesting record as follows:

> Yesterday, the 16th, the air was full of Toxoptera rising on wing, but the breeze was light and they had no chance to travel far. If the wind had favored their flight they must have carried parasites with them as guests, by the myriad, for many of them, probably the major part, were parasitized. [The temperature at Wichita ranged from 44° to 82° F.]

On the same day the senior author, in company with Prof. E. A. Popenoe, in driving about the country in the vicinity of Manhattan, Kans., during the afternoon found that they were in the midst of swarms of winged Toxoptera; frequently a number of individuals might be noted crawling about over their hats and coats and to an annoying degree traveling over their faces. Two days later, the senior author observed both winged Toxoptera and Aphidius crawling about on the inside of the windows of a Pullman car in which he was traveling over the Santa Fe, crossing central Kansas.

At Plano, Tex., June 4, 1909, Mr. Urbahns learned of a most interesting migration reported to him as having taken place two days before. A farmer, Mr. Foreman, reported to him that "green bugs" were observed flying east, probably coming from out of a very badly infested wheat field, moving with the evening breeze. In this case there was clearly a rapid disappearing of the food supply, precipitating a development to winged adults that were probably forsaking the fields for some other locality affording them a greater abundance of food. It would appear, then, that the influence of winds is more or less dependent upon several other phenomena.

With the natural advance of spring from the South, there would be a continually decreasing supply of fresh, tender, succulent food in the South, while to the North this condition would be reversed. Therefore, with winged viviparous females developing with increasing abundance along the area of a certain latitude, such winged females as were carried south or backward over an area already rendered barren of food would consequently perish. On the other hand, those females that drifted or made their way northward would encounter a continually increasing fresh supply of food; therefore they might be said to follow along with the advance of the spring from the South far into the North, until overtaken by their natural enemies. Then, too, south winds are associated with a warm temperature and north winds with the reverse, as will be seen from Tables IV–VIII, furnished by the United States Weather Bureau. Another factor that must not be lost sight of is that after about the latitude of southern Kansas and Missouri is reached wheat ceases to be the food plant for Toxoptera in spring, and spring oats takes its place in this respect.

Still another factor of greatest importance is in the fact that, with a wind from a southern quarter, blowing strongly under a temperature sufficient to render Aphidius active, both Toxoptera and parasite would thus be carried on the wing perhaps miles to the northward and scattered over fields not previously seriously infested. The following day, or some days after, there might come a north wind with greatly reduced temperature, which, though not sufficiently cold to prevent immediate reproduction on the part of migrant Toxoptera, would yet keep the parasite inactive. That precisely these weather conditions do often occur during years of excessive abundance of Toxoptera is shown by the following tables of the weather (Tables IV–VIII), while the dates thereof show conclusively that both Toxoptera and Aphidius were present and active. This last factor will be further discussed under natural enemies. These tables were compiled for us by the Weather Bureau.

TABLE IV.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, San Antonio, Tex., 1907.*

Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.	Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.
		°*F.*	°*F.*		*Miles per hour.*			°*F.*	°*F.*		*Miles per hour.*
Feb. 1	Clear	81	63	SE.	11	Mar. 3	Clear	80	49	SE.	13
2	Fair	83	48	N.	26	4	do	82	56	SE.	15
3	Cloudy	49	38	N.	22	5	Fair	84	64	S.	16
4	Fair	56	33	NE.	20	6	do	85	64	SE.	18
5	do	47	28	NE.	19	7	Clear	84	64	S.	15
6	Cloudy	43	34	NE.	15	8	Fair	82	66	SE.	18
7	Fair	60	39	N.	22	9	do	80	66	S.	16
8	Clear	68	33	N.	7	10	do	80	57	W.	23
9	do	73	38	S.	15	11	do	85	65	SE.	21
10	do	68	42	N.	22	12	do	87	65	S.	21
11	do	72	44	N.	10	13	do	80	70	NE.	17
12	do	74	36	S.	10	14	do	70	47	N.	36
13	do	78	46	S.	15	15	Clear	70	42	NE.	23
14	do	71	50	N.	24	16	do	76	46	SE.	14
15	do	70	40	N.	9	17	do	88	66	SE.	18
16	do	77	44	SW.	11	18	do	88	64	SE.	15
17	do	80	48	SE.	10	19	do	89	62	SE.	15
18	Fair	80	53	SW.	14	20	do	89	63	SE.	17
19	Clear	76	52	N.	18	21	do	88	63	SE.	24
20	do	79	44	SW.	10	22	do	87	64	SE.	20
21	do	80	47	S.	17	23	do	86	66	S.	15
22	Fair	80	52	SE.	19	24	do	88	67	SE.	16
23	Cloudy	79	62	SE.	15	25	Fair	87	68	SE.	18
24	do	67	56	NE.	22	26	do	86	68	SE.	20
25	do	66	48	N.	19	27	do	88	69	SE.	17
26	do	68	49	SE.	7	28	do	88	68	SE.	20
27	Fair	81	63	S.	15	29	Cloudy	73	55	N.	26
28	do	80	64	N.	30	30	Fair	72	55	N.	14
Mar. 1	Clear	73	52	NW.	27	31	Clear	70	52	N.	22
2	do	77	43	S.	14						

TABLE V.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, Fort Worth, Tex., 1907.*

Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.	Date (1907).	Weather	Maximum.	Minimum.	Direction of wind.	Velocity of wind.
		°F.	°F.		*Miles per hour.*			°F.	°F.		*Miles per hour.*
Feb. 1	Fair	71	42	SW.	16	Mar. 3	Clear	82	49	S.	20
2	Cloudy	61	30	NW.	30	4	....do	81	53	SW.	28
3	....do	32	26	N.	17	5	Fair	69	53	SW.	22
4	....do	30	22	NW.	16	6	....do	82	51	SW.	23
5	Fair	33	22	NE.	12	7	....do	86	63	SW.	22
6	....do	42	24	NE.	9	8	....do	70	53	NE.	17
7	....do	53	30	N.	23	9	....do	78	56	SW.	23
8	Clear	67	26	S.	20	10	Clear	62	39	N.	16
9	....do	80	44	S.	17	11	Fair	81	49	S.	35
10	Fair	65	43	NE.	21	12	....do	84	66	SW.	33
11	Clear	73	35	S.	16	13	Clear	78	44	S.	30
12	....do	79	46	SW.	22	14	....do	58	38	N.	20
13	....do	80	47	SW.	22	15	....do	64	39	SE.	11
14	....do	61	42	N.	20	16	....do	75	46	SW.	22
15	....do	69	33	SW.	17	17	Fair	83	63	SW.	24
16	....do	74	45	SW.	15	18	Clear	92	65	SW.	28
17	Fair	79	41	S.	20	19	....do	95	64	SW.	25
18	....do	81	55	NW.	32	20	....do	88	64	S.	24
19	Clear	69	41	N.	16	21	....do	89	63	SW.	25
20	....do	74	40	S.	15	22	....do	87	64	S.	29
21	Fair	74	44	SW.	25	23	Fair	87	65	S.	25
22	....do	58	39	E.	16	24	....do	86	64	S.	20
23	....do	81	52	S.	25	25	Clear	85	67	SW.	31
24	....do	68	44	NW.	23	26	Fair	83	67	SW.	31
25	Cloudy	58	42	NE.	12	27	....do	83	69	SW.	31
26	Fair	71	40	SE.	18	28	....do	84	70	S.	30
27	Cloudy	61	54	SE.	17	29	Cloudy	73	53	NW.	14
28	....do	74	41	NW.	28	30	Clear	70	47	NE.	14
Mar. 1	Clear	56	37	NW.	24	31	....do	59	49	NE.	21
2	....do	81	40	SW.	23						

TABLE VI.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, Oklahoma City, Okla., 1907.*

Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.	Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.
		°F.	°F.		*Miles per hour.*			°F.	°F.		*Miles per hour.*
Mar. 1	Clear	49	28	N.	30	Apr. 1	Fair	66	38	S.	34
2	....do	68	35	S.	35	2	....do	75	48	S.	52
3	....do	69	37	E.	23	3	....do	88	58	SW.	43
4	Cloudy	84	45	S.	36	4	Cloudy	68	54	N.	36
5	....do	55	34	N.	36	5	....do	58	42	N.	38
6	....do	68	48	S.	38	6	....do	72	48	SE.	34
7	Fair	60	44	N.	34	7	Clear	71	47	N.	24
8	Cloudy	54	35	E.	25	8	....do	63	44	N.	38
9	....do	71	38	NW.	47	9	Fair	79	41	W.	31
10	Fair	48	35	N.	35	10	Clear	74	43	S.	26
11	Cloudy	70	39	S.	36	11	....do	72	52	N.	42
12	Fair	68	43	S.	30	12	Fair	58	42	N.	36
13	Cloudy	44	32	N.	32	13	....do	57	33	NE.	22
14	Fair	54	27	N.	22	14	Cloudy	61	44	S.	32
15	....do	62	36	S.	25	15	....do	85	49	SE.	48
16	....do	71	42	S.	38	16	....do	64	34	NE.	38
17	....do	83	52	S.	37	17	....do	54	34	SE.	24
18	....do	89	60	S.	35	18	Fair	65	41	SE.	37
19	....do	97	63	S.	32	19	Cloudy	52	39	N.	26
20	Clear	92	61	S.	25	20	....do	48	36	NE.	26
21	....do	89	64	S.	32	21	....do	51	44	NE.	18
22	....do	86	63	S.	34	22	....do	46	40	N.	22
23	Fair	84	64	S.	31	23	Clear	69	36	S.	30
24	Cloudy	88	54	S.	35	24	Fair	79	52	S.	48
25	Fair	86	64	S.	38	25	Cloudy	64	40	N.	42
26	Cloudy	77	67	S.	47	26	Clear	66	35	NE.	20
27	....do	83	68	S.	38	27	Cloudy	80	55	S.	36
28	....do	82	61	S.	42	28	Fair	77	51	SE.	36
29	Fair	68	46	W.	22	29	Cloudy	64	34	N.	44
30	....do	70	42	N.	31	30	Fair	50	32	N.	30
31	Cloudy	55	44	N.	34						

TABLE VII.—*Maximum and minimum temperatures, with direction and velocity of wind, and character of the day, Wichita, Kans., from Mar. 20 to May 31, 1907.*

Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.	Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.
		°*F.*	°*F.*		*Miles per hour.*			°*F.*	°*F.*		*Miles per hour.*
Mar. 20	Clear	87	51	SW.	16	Apr. 26	Clear	63	31	SE.	13
21	....do	91	63	SW.	24	27	Fair	77	48	SE.	19
22	Fair	92	63	SW.	24	28	Cloudy	63	41	N.	18
23	Clear	78	64	SW.	21	29	....do	41	32	N.	27
24	....do	85	54	S.	19	30	Fair	49	30	N.	16
25	....do	89	62	SW.	24	May 1	Clear	61	31	SW.	9
26	Cloudy	78	69	SW.	28	2	Fair	67	45	E.	14
27	Fair	69	47	SW.	17	3	Cloudy	51	30	N.	27
28	Cloudy	79	52	W.	30	4	Fair	50	28	SE.	15
29	Clear	68	39	NW.	15	5	Cloudy	50	43	NE.	13
30	Fair	68	42	N.	21	6	....do	51	45	NW.	15
31	....do	57	39	NE.	17	7	....do	57	46	N.	9
Apr. 1	Clear	65	37	S.	24	8	Fair	66	50	N.	12
2	Fair	71	49	S.	30	9	....do	72	49	SE.	9
3	Clear	81	56	NW.	24	10	....do	79	51	NE.	11
4	Fair	71	44	NE.	26	11	Clear	80	52	SE.	20
5	....do	60	39	NE.	20	12	....do	82	60	S.	35
6	Cloudy	57	42	W.	15	13	Cloudy	79	50	S.	24
7	....do	62	44	W.	23	14	....do	53	37	N.	27
8	Clear	60	41	N.	30	15	Fair	66	33	NW.	22
9	....do	74	35	N.	23	16	Clear	82	44	S.	16
10	Fair	63	39	SE.	16	17	Fair	90	60	SW.	19
11	Clear	66	44	NW.	23	18	Cloudy	86	58	SW.	12
12	....do	55	36	NW.	26	19	Fair	71	58	NE.	14
13	Fair	53	28	N.	13	20	Clear	79	50	SE.	16
14	Cloudy	52	36	SE.	22	21	Fair	85	61	SW.	24
15	Fair	74	46	N.	18	22	Clear	85	65	SW.	25
16	Cloudy	51	29	NE.	22	23	Fair	86	66	SE.	18
17	Fair	58	25	SE.	14	24	Cloudy	75	64	SW.	17
18	....do	53	36	N.	25	25	Fair	82	55	NW.	14
19	....do	53	32	N.	14	26	....do	65	48	N.	26
20	Cloudy	52	37	NE.	14	27	Clear	66	37	N.	14
21	....do	58	34	N.	9	28	Cloudy	54	54	SW.	16
22	....do	56	43	S.	11	29	....do	59	69	E.	10
23	Clear	73	36	SW.	17	30	....do	61	61	N.	13
24	....do	81	45	SW.	34	31	....do	65	65	N.	21
25	Fair	53	36	NE.	24						

TABLE VIII.—*Maximum and minimum temperatures with direction and velocity of wind, and character of the day, Dodge City, Kans., from Mar. 20 to May 31, 1907.*

Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.	Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.
		°*F.*	°*F.*		*Miles per hour.*			°*F.*	°*F.*		*Miles per hour.*
Mar. 20	Fair	91	41	SE.	24	Apr. 8	Fair	63	41	NW.	23
21	....do	94	54	SW.	28	9	Clear	73	40	NW.	16
22	....do	89	43	S.	28	10	....do	77	37	SE.	27
23	Clear	76	53	NW.	23	11	....do	64	38	NW.	24
24	....do	86	46	S.	26	12	Fair	59	35	NW.	15
25	Fair	89	46	SE.	30	13	Clear	55	28	E.	13
26	....do	85	54	SE.	36	14	....do	68	35	SE.	26
27	....do	61	38	NW.	16	15	Fair	70	39	NW.	23
28	....do	74	44	SE.	35	16	Cloudy	48	24	NE.	14
29	Clear	62	30	NW.	24	17	Clear	60	24	SE.	16
30	Cloudy	59	31	NW.	18	18	Fair	51	32	NW.	18
31	Fair	55	34	SE.	16	19	Cloudy	45	30	NE.	10
Apr. 1	Clear	72	36	SE.	28	20	....do	46	33	NE.	9
2	Fair	85	51	E.	23	21	....do	48	28	SE.	10
3	Clear	73	49	NW.	22	22	Fair	56	35	SE.	9
4	Cloudy	58	38	N.	15	23	Clear	78	30	SE.	18
5	Fair	61	26	SE.	10	24	....do	76	36	W.	24
6	....do	67	39	W.	25	25	Cloudy	44	31	NW.	17
7	Clear	66	33	SW.	12	26	Fair	64	28	SE.	18

TABLE VIII.—*Maximum and minimum temperatures with direction and velocity of wind, and character of the day, Dodge City, Kans., from Mar. 20 to May 31, 1907*—Contd.

Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.	Date (1907).	Weather.	Maximum.	Minimum.	Direction of wind.	Velocity of wind.
		°F.	*°F.*		*Miles per hour.*			*°F.*	*°F.*		*Miles per hour.*
Apr. 27	Clear	81	37	N.	16	May 15	Clear	67	30	W.	10
28	Fair	59	32	N.	16	16	....do	86	42	SE.	7
29	Cloudy	42	25	N.	18	17	Fair	92	53	SE.	17
30	Fair	45	20	NW.	7	18	Cloudy	81	55	NE.	13
May 1	....do	62	37	SE.	12	19	Clear	73	50	N.	10
2	Cloudy	67	32	NW.	18	20	Fair	81	50	SE.	24
3	Fair	38	27	NW.	20	21	....do	86	60	SE.	35
4	....do	57	27	SE.	22	22	Clear	88	65	SE.	33
5	Cloudy	48	41	SE.	8	23	Fair	87	64	SE.	32
6	....do	50	42	NE.	7	24	....do	78	55	SE.	29
7	....do	60	40	E.	8	25	Clear	74	47	W.	41
8	Fair	68	43	N.	6	26	....do	62	37	NW.	36
9	Clear	71	49	E.	10	27	....do	64	30	SE.	16
10	....do	78	45	NW.	5	28	Cloudy	52	42	SE.	28
11	....do	84	48	SE.	24	29	....do	58	46	SE.	22
12	....do	90	60	SE.	31	30	....do	59	49	N.	11
13	Fair	70	39	NW.	17	31	Fair	67	48	NW.	24
14	Clear	55	34	NW.	16						

INFLUENCE OF TEMPERATURE ON DIFFUSION.

Directly and indirectly, temperature is responsible for the destructive abundance of *Toxoptera graminum* in the United States. Directly, because the species will breed throughout the winter months at a temperature under which its natural enemies will remain inactive, and besides, it is probably due to this influence that the sexual forms and eggs occur, so far as known, only over the northern portion of its range. Our extended investigations have led to the suspicion that, but for the viviparous reproduction in such overwhelming numbers in the South, during winter end early spring, to drift northward with the season, there would be little if any damage caused by its occurrence in the Northern States, where in fairly severe winters it probably winters over in the egg stage only. For this reason the authors have thought investigations of the egg and its development of decided economic as well as scientific importance, and the junior author has therefore made a brief study of the embryology of the species.

The temperatures prevailing over the country where Toxoptera has worked its most serious ravages, and departures from the normal during the season of greatest activity are all given on the temperature diagrams, Nos. I to V (pp. 15, 21, 25, 26, 28). The upper numbers indicate the normal temperature, the lower the departure therefrom ("+" meaning above and "–" below). Each separate page relates to one of each of the five consecutive outbreaks. From these it will be seen that outbreaks of Toxoptera have succeeded only winters with

the temperature in the South above the normal, followed by springs during which the temperature was below the normal. The temperature during December, 1902, was below the normal in the Southwest. (See Diagram II.) In January, 1903, it was above, but below again in February, and about normal or above in March and April, the result being that only incipient outbreaks occurred in northern Texas and probably South Carolina. (See Diagram II; fig. 5, p. 20.) If the series of temperature maps (Diagrams I–V) be compared with those showing the area covered by each invasion the relation between abnormal temperatures and these invasions will be clearly apparent.

These records are those of the United States Weather Bureau and are therefore correct so far as general field temperatures are involved. When it comes to a consideration of the exact effects of temperature and humidity upon the individual Toxoptera, however, the figures will not apply with mathematical exactness, for the reason that to secure this information it is necessary to learn the exact conditions in the midst of the insects themselves at the exact time that such data are being secured. To illustrate, the instruments of the Weather Bureau kept in the shade may indicate a certain temperature, yet in a field perhaps a mile distant on a sunny day, and down among the plants in the midst of the developing insects, there may be several degrees difference in temperature. As will be noted farther on, Mr. Luginbill has found this difference to amount in some cases to several degrees. Besides, it is easy to conceive of other conditions which might have precisely the reverse effect. Furthermore, there will be a difference in temperature as between fields with a sandy and a clay soil or between a southern and a northern exposure, or with a soil dry on the surface as against a soil with a wet surface. It will be observed, therefore, that while the exact temperature at which Toxoptera will reproduce, viviparously, is of scientific interest, such information is of minor significance in the field, where it is the more generally prevailing weather conditions, such as are secured by the United States Weather Bureau, over wide areas that become of greatest importance, Mr. R. A. Vickery, on December 4, 1908, at Richmond, Ind., with 5 viviparous females under observation, found that young were produced sparingly at a temperature of 40° F. This was indoors, in a room slightly heated by an oil stove so that the temperature was under control, and frequent readings were made during the day. Under the same conditions numerous young were produced when the temperature reached 45° to 53° F.

Tabulated, the results of Mr. Vickery's rearings are as follows:

TABLE IX.—*Experiments with 5 viviparous females of Toxoptera graminum to determine minimum temperature at which reproduction will take place. Richmond, Ind., December, 1908.*

Date.	Temperature.		Number of young produced.
	Minimum.	Maximum.	
	°F.	*°F.*	
Dec. 3	40	45	0
4	40	41	1
5	40	53	6
6	40	45	0
7	26	49	1
8	35	50	7
9	39	50	0

After December 9 the outside temperature increased so that control indoors was not possible.

At Dallas, Tex., January 3 to 14, out of doors and under natural conditions, with thermometer within a few feet of the five female Toxoptera 1 to 3 days after maturity, Mr. Urbahns found that young were produced as follows:

TABLE X.—*Experiments with 5 viviparous females of Toxoptera graminum to determine minimum temperature at which reproduction will take place. Dallas, Tex., January, 1908.*

Date.	Temperature.		Number of young produced by each individual.					
	Minimum.	Maximum.						
	°F.	*°F.*						*Total.*
Jan. 3	47	68	1	1	1	1	1	5
4	55	78	3	3	1	5	4	16
5	37	69	3	3	1	2	2	11
6	22	42	0	0	0	0	0	0
7	21	32	0	0	0	0	0	0
8	29	45	0	0	0	0	0	0
9	44	74	4	2	0	3	4	13
10	37	74	4	4	(1)	3	5	16
11	14	15	0	0	......	0	0	0
12	10	22	0	0	......	0	0	0
13	21	32	0	0	......	0	0	0
14	32	71	0	0	......	0	0	0
Total..	....	....	15	13	3	14	16	......

[1] Died.

Further observations made by Mr. Urbahns on these same dates with eight additional females, the offspring of which were not counted, are of much interest and are given herewith.

January 3. Two reproducing.
January 4. Four reproducing, 1 pupating.
January 5. Five reproducing.
January 6. All torpid, seemingly frozen.
January 7. All torpid, seemingly frozen.
January 8. All torpid, none reproducing.
January 9. Seven reproducing, 1 still pupa.
January 10. Seven reproducing, 1 still pupa.
January 11. All torpid, seemingly frozen.
January 12. All torpid, seemingly frozen.
January 13. All torpid, seemingly frozen.
January 14. Adults and young fallen from the plants and lying on the ground. All except 3 inactive.

One female of the first five died on the 10th and nearly all of the others survived but a few days; only one was alive on the 20th.

During the spring of 1908 the junior author was engaged in an extensive series of rearing experiments at Richmond, Ind. Both plants and insects were kept out of doors in a small rearing house (see Pl. II, fig. 1), with a thermograph placed in their midst, so that exact temperature changes were continuously recorded. Plants were grown in flowerpots and over them in each case was placed a lantern globe with the top covered with cheesecloth. Whatever the effect of this inclosure and cover might have been it was evidently uniform and, therefore, affected all of the viviparous female Toxoptera on these plants to the same degree.

Taking five viviparous females, each a stem mother, colonized separately on single plants, in a precisely similar inclosure, and keeping a record of the number and date of young born, we have the following tabulated results:

TABLE XI.—*Effect of temperature on reproduction of Toxoptera graminum, Richmond, Ind., 1908.*

Date.	Temperature. Minimum.	Temperature. Maximum.	Number young produced by each individual.					Total No.
	°*F.*	°*F.*						
Apr. 18...	55	63	2	....	2	0	2	6
19...	50	70	4	2	2	1	2	11
20...	39	68	2	2	2	0	0	6
21...	33	68	2	2	2	1	0	7
22...	35	74	2	1	1	1	1	6
23...	52	79	2	5	5	1	1	14
24...	60	71	3	3	4	0	1	11
25...	61	74	3	4	5	1	2	15
26...	53	80	3	5	3	3	0	14
27...	42	67	0	2	2	3	1	8
28...	38	54	2	0	0	0	0	2
29...	36	46	1	0	2	3	1	7
30...	33	47	0	0	0	0	0	0

Date.	Temperature. Minimum.	Temperature. Maximum.	Number young produced by each individual.					Total No.
	°*F.*	°*F.*						
May 1.....	29	56	0	0	0	0	0	0
2.....	35	47	0	2	1	0	0	3
3.....	37	55	1	2	2	1	0	6
4.....	41	50	0	0	0	0	0	0
5.....	49	52	0	0	0	0	1	1
6.....	49	76	1	2	2	0	0	5
7.....	41	63	0	0	1	0	0	1
8.....	41	49	1	0	0	0	0	1
Total..............			29	32	36	15	12	....
Total progeny during life..................			60	47	69	39	29	....

Of the five individuals involved in Table XI the two last hatched from the egg March 24, the other three on March 27. This table indicates the influence of high temperatures on reproduction, but also shows that these affect the individual female to varying degrees. The totals for the life of individual females show that all of these were in the vigor of life, not having reached the decline at the time the observations were made.

These tabulations are taken from records of regular rearing and reproduction investigations, and were selected wherever there occurred a number of consecutive days with temperatures varying both above and below freezing during each 24 hours.

By referring to the continuous rearing by the junior author it will be observed that with favorable conditions a female Toxoptera will produce young every day during the most vigorous portion of her life, the exceptions being toward the close thereof.

It would probably be well to mention in this connection some observations of the junior author in regard to the amount of cold that can be endured by Toxoptera.

On November 13, 1908, several viviparous females that had been producing young were frozen solidly in a block of ice. They were thawed out after 8 and 24 hours, respectively, and all died. These may have been somewhat weakened by age, however, so on the 14th 2 oviparous females, 1 winged viviparous female, 1 adult viviparous, and 2 individuals that had cast the third molt were frozen in a block of ice and allowed to remain so for 24 hours. About an hour after being thawed out, at a temperature of about 45° F., 1 oviparous female and the winged female turned dark and died, the others keeping color, but showing little signs of life. About 3 hours after there were signs of life among the remaining ones; 7 hours after thawing out they were still feeble; 24 hours after thawing out the temperature was raised to 60° F and 1 molted. On the third day after being thawed out there were 2 young in the cage. Six days later all were dead except the one that was giving birth to young, and her progeny. This will give some idea of the tenacious grip Toxoptera has on life.

Attention may properly be called to the fact that unless the utmost caution is employed in the examination of plants for newly-born young there is great likelihood that some of them may be overlooked. Thus they may be born one day under a high temperature but remain undiscovered until later, when the temperature is much lower, and of course be credited to the later date. In the light of all of the observations made by those engaged in these investigations, the minimum temperature under which reproduction begins is about 40° F. Possibly reproduction may occur under some obscure favorable circum-

stances at a slightly lower temperature, but these instances are probably too infrequent to become of economic importance.

With the eggs in the North the case may be more important, because these, deposited in dead leaves of bluegrass, and sometimes probably buried under several inches of this matted grass, with the living leaves covering this over, the temperature and moisture would both be greater than at several feet above ground without such protection. Mr. Philip Luginbill of this bureau in April, 1911, proved this to be true. He placed a thermometer in just such a position as mentioned above, in a protected nook where the sun could shine directly on it in the grass and no wind could reach it and found that the temperature was 10° to 12° F. higher than when the thermometer was several feet above the ground and in the shade. The junior author has found that eggs are deposited in just such places, and that hatching takes place in spring at a temperature ranging, as recorded by the thermograph, from 32° to 62° F. It would appear that eggs deposited in a position as mentioned above would hatch sooner than those deposited in places where the temperature would not be so high and the stem mothers from the former would reproduce, the pest becoming more abundant in the spring and making its way from grass to grain earlier and in greater numbers than they would from the cooler locations.

This leads us to a very interesting and important point in temperature effects on the species. In the South, seemingly south of about latitude 35° to 36° north, it has been impossible to find eggs of this and other species of aphidids in the fields. There is in the perpetuation of the species no apparent need of this stage, however, as it is able to continue throughout the entire year reproducing viviparously. In the North this is probably not possible except during very mild winters. The situation is therefore about like this: Gradually as we proceed southward from about latitude 38° the sexual forms and eggs disappear, while to the north of about latitude 36° hibernation is confined more and more to the egg stage, until this becomes exclusively the state in which the winter is passed.

The practical, economic importance of this is that there is considerable doubt relative to the amount of injury the pest would cause north of this belt of country if there were no Toxoptera drifting in from the south. In other words, but for the countless myriads developing south of this belt and sweeping over and beyond it, there would be few if any destructive ravages. If this is the true state of affairs, the oats crop north of this belt is to a certain degree dependent upon the success or failure in controlling the pest in Texas, Oklahoma, New Mexico, and South Carolina.

Summarizing, then, it would appear from the information we have been able to obtain, and which is given throughout this publication,

together with that contained in the various tables and diagrams relating to temperature effects upon this insect: (1) That mild winters are of much more vital importance in Texas than they are in the latitude of southern Kansas and northward, and (2) that the influences of abnormally warm weather, if the temperature rises high enough, have the effect of bringing about activity among the parasites, which has a restraining effect upon the increase of Toxoptera.

In the North, where the pest winters over wholly or largely in the egg stage, warm winters are of less importance, while abnormally cool weather during spring and early summer exerts a far greater influence. This fact renders a study of the embryology and temperature effects upon eggs and stem mothers necessary to a full understanding of the entire problem, extending as it does over both North and South.

The fact just stated is somewhat peculiar and was unexpectedly revealed by the combined studies of those engaged in the investigation of the insect, and called for a study of the development of the egg, which has been carried on by the junior author with the results given in the following pages. The most important influence of temperature is, of course, upon the development of its principal natural enemy, *Aphidius testaceipes*, further discussed in connection with the studies of that insect.

EMBRYOLOGY.

Although the development of the parthenogenetic egg in Aphididæ has received considerable attention from several authors, that of the true egg has received very little study. Hence the junior author has given a limited amount of time to the study of certain important phases in the development of the winter egg, as contrasted with the winter condition of the viviparous insect in the South.

Not wishing to duplicate the work of the other writers, who have confined their studies for the most part to the earlier stages of development, he has begun with the formation of the blastoderm, his main object being to follow the principal stages of development of the embryo through the fall until growth is checked by freezing temperatures, to note the time when growth is resumed in spring, and to observe the effect of varying temperatures on development, all of which has to do with the fluctuations of the insect in point of numbers in the North and relates to its economic importance, besides balancing our knowledge of the insect at a corresponding season in the South.

Most of these studies were carried out at the University of Illinois under the supervision of Dr. J. W. Folsom. We are deeply indebted both to him and to Dr. W. M. Wheeler of Harvard University for their kindly criticisms and helpful suggestions.

METHODS AND MATERIAL.

The material used in this investigation was collected in the autumn of 1908 at Richmond, Ind., and in 1909 and 1910 at La Fayette, Ind. The eggs were killed and fixed mainly in two solutions that are practically the same. The first was a saturated solution of bichlorid of mercury (corrosive sublimate) in 35 per cent alcohol, 95 volumes, and glacial acetic acid, 5 volumes. The second was a saturated solution of bichlorid of mercury in 50 per cent alcohol, 94 volumes, and glacial acetic acid, 6 volumes. The fixing fluid was raised to a temperature of 75° to 80° C., poured over the living specimens, and allowed to act from 5 to 10 minutes, after which it was replaced by the same solution, cold, for an equal length of time. The specimens were then washed in 70 per cent alcohol, in which they were kept until sectioned. Gibson's fluid was found to be a very good killing and fixing agent also.

For sectioning, the following method was employed: The eggs were punctured with a fine needle, dehydrated, and kept 20 to 30 minutes in paraffin of about 54° C. melting point. They were oriented in a watch glass (that had previously been smeared with glycerin) with a hot needle, under a binocular microscope, the bottom of the watch glass being first quickly cooled with a little cold water.

The eggs were cut with a Minot-Zimmermann microtome in sections from 8 to 13 μ in thickness, attached to the slide with Mayer's albumen fixative, and stained with Delafield's hæmatoxylin or by Heidenhain's iron-alum-hæmatoxylin method.

Surface views of the embryo were obtained by dissection. For dissections it was found that the best results were obtained by using material that had been freshly fixed and washed. Grenacher's alcoholic borax-carmine was used for staining in toto.

GENERAL DESCRIPTION OF THE EGG.

The eggs are broadly elliptical with a slight reniform tendency. They are 0.70 to 0.78 mm. in length and 0.33 to 0.45 mm. broad.

At oviposition the egg is a very pale yellow, changing in a few hours, at a temperature of 50° to 70° F., to a faint greenish color. At this stage there appears an almost circular area of darker green at one pole of the egg; we have termed this the "ovarian yolk," a brief description of which occurs in the following pages. At the end of 24 hours the walls of the egg about the ovarian yolk appear denser and of a deeper green. The germ band is now forming and invaginating. During the next 24 hours this process is completed, the egg becoming a darker green in the meantime. By the third day a rod-shaped body can be seen near the center of the egg. This object is the submerged germ band. By the end of the third day the egg becomes black.

All these changes can be readily observed with a hand lens by holding the egg up to the light. At low temperatures (below 40° F.) these changes take place slowly, 10 or more days being required for the egg to turn black, if the temperature is near the freezing point. The black coloration is apparently due to a pigment in the shell; the green color, to the developing embryo.

At deposition the egg is coated with a viscous substance which hardens in a few days, fixing the egg firmly to the object upon which it rests.

There are but two membranous coverings to the ripe egg, the chorion, or shell covering, and the vitelline membrane.

The chorion is a rather tough, leathery, homogenous membrane which under a hand lens appears smooth and shining. With a compound microscope very faint lines or cracks can be sometimes observed on the surface, although usually the surface appears perfectly smooth, with no markings whatever.

The vitelline membrane is structureless, colorless, and transparent. Under the vitelline membrane is the peripheral layer of protoplasm. This layer is very thin and very finely reticular. It is continuous over the surface of the egg, the cleavage cells lodging in it to form the blastoderm.

Internally the egg consists chiefly of a compact mass of yolk granules, supported within the meshes of almost clear protoplasm. The yolk granules are structureless and subspherical in shape and vary greatly in size, ranging from 0.0027 mm. to 0.013 mm. in diameter.

At the posterior pole of the egg is a large, dense, almost spherical, granular mass. These granules are 0.0019 mm. in diameter, are almost uniform in size, and the central area apparently takes the stain slightly as though it were a chromatinlike substance. As previously stated, we have termed this mass the ovarian yolk. It is evidently not homologous to the secondary yolk of the parthenogenetic embryos. The ovarian yolk is formed approximately at the same time as the formation of the main yolk mass of the egg, while in the case of the parthenogenetic forms of aphidids the secondary yolk enters the egg as the blastoderm is forming. It appears also, from our material, that this ovarian yolk is not exactly homologous to the "pole disk" described and observed by Hegner (1908), as we have not been able to observe that it affects the nuclei in any way, nor have we found any cells which we think correspond to his "pole cells." The function of this granular mass seems to be the nourishment of the developing ovaries, and we have therefore called it ovarian yolk. It is not entirely used up in the early stages of embryonic growth, and remains in close proximity to the developing ovaries throughout the later stages.

Tannreuther (1907, pp. 631, 632) states that in the species he studied some of the follicular nuclei of the wall of the oviduct which enter the posterior pole of the egg divide several times, the chromatin breaking up into smaller parts and becoming vesicular. These small vesicles then usually unite and form a common spherical mass, though in some cases they remain isolated.

In *Toxoptera graminum* we find no trace of true nuclei within the ovarian yolk (the homologue of Tannreuther's secondary york of the winter egg) until the blastoderm is formed, at which time cells may be found that are apparently migrants from the primary yolk.

OBSERVATIONS.

For convenience of reference 9 consecutive stages of development are here designated, as follows:

Stage 1 (Pl. III, fig. 1).—Blastoderm just forming, only part of the surface being covered by the cleavage cells.

Stage 2 (Pl. III, figs. 2–4).—This shows early and later stages of invagination of the germ band. The position of the ovarian yolk in relation to the invaginating germ band is shown here.

Stage 3 (Pl. IV, fig. 1).—The germ band is still adhering to the posterior pole of the egg.

Stage 4 (Pl. IV, figs. 2, 3).—The germ band is entirely submerged in the yolk, is tubular in form, and uniform in thickness.

Stage 5 (Pl. IV, fig. 4).—During the fifth stage the germ band has differentiated into the amnion and the germ band proper.

Stage 6 (Pl. V, fig. 1).—The germ band shows differentiation into layers, and the fundaments of the segments are evident.

Stage 7 (Pl. V, fig. 2; Pl. VI, fig. 1).—The fundaments of the appendages have appeared and the invaginations for the stomodæum and the salivary glands are evident.

Stage 8 (Pl. V, fig. 3; Pl. VI, fig. 2).—The appendages are much longer, and the invaginations for the stomodæum and proctodæum are well advanced. The latter is not indicated in Plate V, figure 3, as the last segment curves backward too far.

Stage 9 (Pl. VII, figs. 1, 2, 3, 4).—The illustration of this stage is intended mainly to show the manner in which the embryo reaches the surface and the position of the dorsal organ.

In *Stage 1* (Pl. III, fig. 1) the blastoderm is beginning to form. As the cleavage cells become more numerous within the yolk-mass some of them migrate to the surface and lodge within the peripheral layer of protoplasm, where, according to Tannreuther (1907), they divide again, the protoplasm of the nuclei merging with that of the peripheral layer. The formation of the blastoderm takes place more rapidly in the region of the anterior pole, the posterior being the last covered;

the entire layer is then one cell in thickness. The blastoderm, however, does not cover the surface of the ovarian yolk.

Not all of these cleavage cells reach the surface; many remain behind, increasing in number within the yolk. These latter cells are indistinguishable from those of the blastoderm. Figs. 1a and 1b represent two of these cells magnified 845 diameters, showing them to be star-shaped masses of protoplasm with a large oval coarsely granular nucleus, more often with a large clear area of nuclear substance around the mass of chromatin granules.

At the posterior pole, about the ovarian yolk, the blastoderm begins to thicken and to invaginate (Stage 2, Pl. III, figs. 2–4). This is the beginning of the germ band. At this stage (*Stage 2*) some of the yolk cells apparently pass into the ovarian yolk. Tannreuther (1907, p. 631) states that the thickening of the blastoderm is caused by the rapid division of the blastoderm cells of this particular part. We find, in addition, that some of the cells from the interior of the egg migrate to the posterior pole to assist in this process. Each of the cells of this thickened area is very elongate, and, from a surface view, now has a somewhat polygonal shape, with a large coarsely granular nucleus. The growth of the cells of the germ band carries the ovarian yolk toward the center of the egg (see Pl. III, fig. 4). The part of the blastoderm that invaginates first becomes the posterior part of the embryo, and that part that invaginates last becomes the anterior portion.

In *Stage 3* (Pl. IV, fig. 1) the germ band is ready to free itself from the blastoderm. The former is now cone-shaped, the base being closed by the ovarian yolk.

When the germ band releases itself from the blastoderm, it leaves behind what we have termed the "polar organ:" A cluster of cells embedded within a mass of protoplasm. These cells soon group themselves into a more or less spherical mass, with a less dense vacuolar area at the center (see Pl. IV, fig. 4). In later stages this central area appears denser and structureless, as though filled with a fluid, and is of a yellow color, not taking the stain, and opening directly upon the surface of the egg. For these reasons we suggest that it may be an organ of excretion. When development ceases in the fall, this body is still present.

What was formerly the blastoderm now becomes the serosa. The cells are much more widely spaced now and this wall is much thinner, except at the anterior pole, where the cells are apparently crowded more closely than before. Some of these cells often show large vacuoles on the side toward the yolk.

At *Stage 4* (Pl. IV, fig. 2) the germ band is completely submerged in the yolk, has assumed a tubular shape, and is near the center of the egg. The walls are of uniform thickness and composed of a com-

pact mass several cells thick, some of which are vacuolated, and having a coarsely granular nucleus. Figure 3 of Plate IV shows a cross section—slightly oblique, however—of the germ band.

The yolk granules of the primary yolk are now more numerous near the embryo.

In *Stage 5* (Pl. IV, fig. 4) the germ band has clearly differentiated into the amnion and the embryo proper; these gradually merge into each other. This differentiation apparently takes place by a gradual migration of cells to one side of the germ band. The cells of the amnion at this time resemble very closely those of the germ band proper. The germ band begins to fold in this stage and its anterior extremity begins to broaden and flatten. The ovarian yolk has decreased in volume and has assumed a more anterior position in relation to the embryo. The yolk cells in both the primary and ovarian yolk have lost somewhat their amœboid character, and now consist, each, of a large granular nucleus, with a much thinner area of protoplasm about it. The primary yolk granules are smaller and much less numerous than before and are collecting in masses about the yolk cells, with indications here and there of a partition, or wall, forming between them. This stage is reached by the end of the second day, under favorable weather conditions.

The "polar organ" and protoplasm at the posterior pole contain a large central vacuolar area now.

In *Stage 6* (Pl. V, fig. 1) the germ band has greatly increased in length, is folded upon itself, and almost forms a loop, the anterior and posterior extremities nearly touching, and both pointing to the posterior pole. A portion of the posterior extremity of the germ band is again folded upon itself. It is now differentiated into three layers, which we take to be, respectively, ectoderm, mesoderm, and entoderm. The ectoderm and mesoderm consist of a compact mass of columnar cells, two cells thick. The entoderm is much thinner and less compact and forms an almost continuous sheet over the inner surface of the germ band. Its cells resemble yolk cells very closely.

In this stage fundaments of the body segments appear as slight elevations of the ectodermal surface. The ovarian yolk has assumed a more anterior position in relation to the embryo than in the preceding stage. Between the ovarian yolk mass and the germ band is a group of cells that have apparently separated off from the mesoderm. From this group of cells, in later stages, the generative organs arise. The amnion now covers the ventral surface of the embryo and the other surface of the embryo is in contact with the yolk. The amnion is a very thin, delicate membrane, its cells being widely spaced and quite small. The intervening protoplasm between the cells of the serosa has become more constricted and the cells have taken more of an elongated oval shape. The primary yolk has now become defi-

nitely segmented into more or less spherical masses, separated by thin walls, each area or mass containing a number of yolk granules and from one to several cells. The polar organ is now almost spherical, with a central, pear-shaped area of dense, structureless, non-staining matter of a yellowish color, and an anterior opening. Although this evidence is insufficient it possibly indicates that the function of this organ is excretory. The embryo reaches this stage of development about the third day, under favorable conditions of temperature.

In *Stage 7* (Pl. VI, fig. 1) the embryo has changed its position so that from a side view it has the form of a reversed figure 6. The portion that in the preceding stage was folded upon itself ventrally has reversed its position and folded back dorsally. The ovarian yolk is now in the region of the first abdominal segments. It is in contact with the embryo, and the group of cells that separated it from the embryo in the preceding stage has assumed almost a spherical form, and a more posterior position, forming the genital organs later on.

The three primary regions, cephalic, thoracic, and abdominal, are now sharply marked. Each region is distinctly segmented. The cephalic region has 5 segments indicated, the thoracic 3, and the abdominal 9, the last abdominal being relatively quite large. There are now 15 conical appendages. The antennæ arise from the posterior margin of each cephalic lobe. The labrum is between and slightly anterior to the antennæ. The mandibles are nearer the median plane than the fundaments of the maxillæ and the labium. The next three pairs of appendages represent the first, second, and third pairs of legs. Plate V, figure 2, represents a surface view of stage 7, showing the embryo straightened out and the position of the appendages. All of these appendages are evaginations of the ectoderm, cross-sections showing an external layer of ectoderm cells and an inner layer of mesoderm cells.

The stomodæum (Pl. VI, fig. 1) appears now as a simple invagination of the ectoderm, the posterior wall of the labrum forming its anterior wall. The proctodæum has not yet appeared, The salivary glands (Pl. VI, fig. 1) are represented by a deep, bilobed, ectodermal invagination between the cephalic and thoracic regions. There is now a star-shaped mass of protoplasm about the nucleus of the ovarian yolk cells and the yolk granules are grouped around these cells.

The primary yolk is grouped very much as in the preceding stage with the exception that the masses are smaller and do not contain as many nuclei.

The polar organ is smaller than formerly, with a smaller number of cells. It still contains a yellowish mass and communicates with the outer surface of the egg.

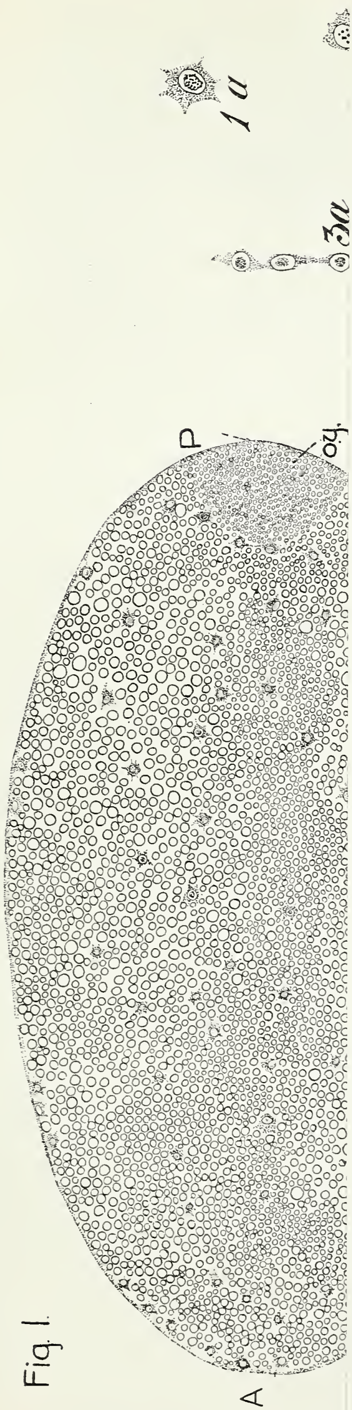
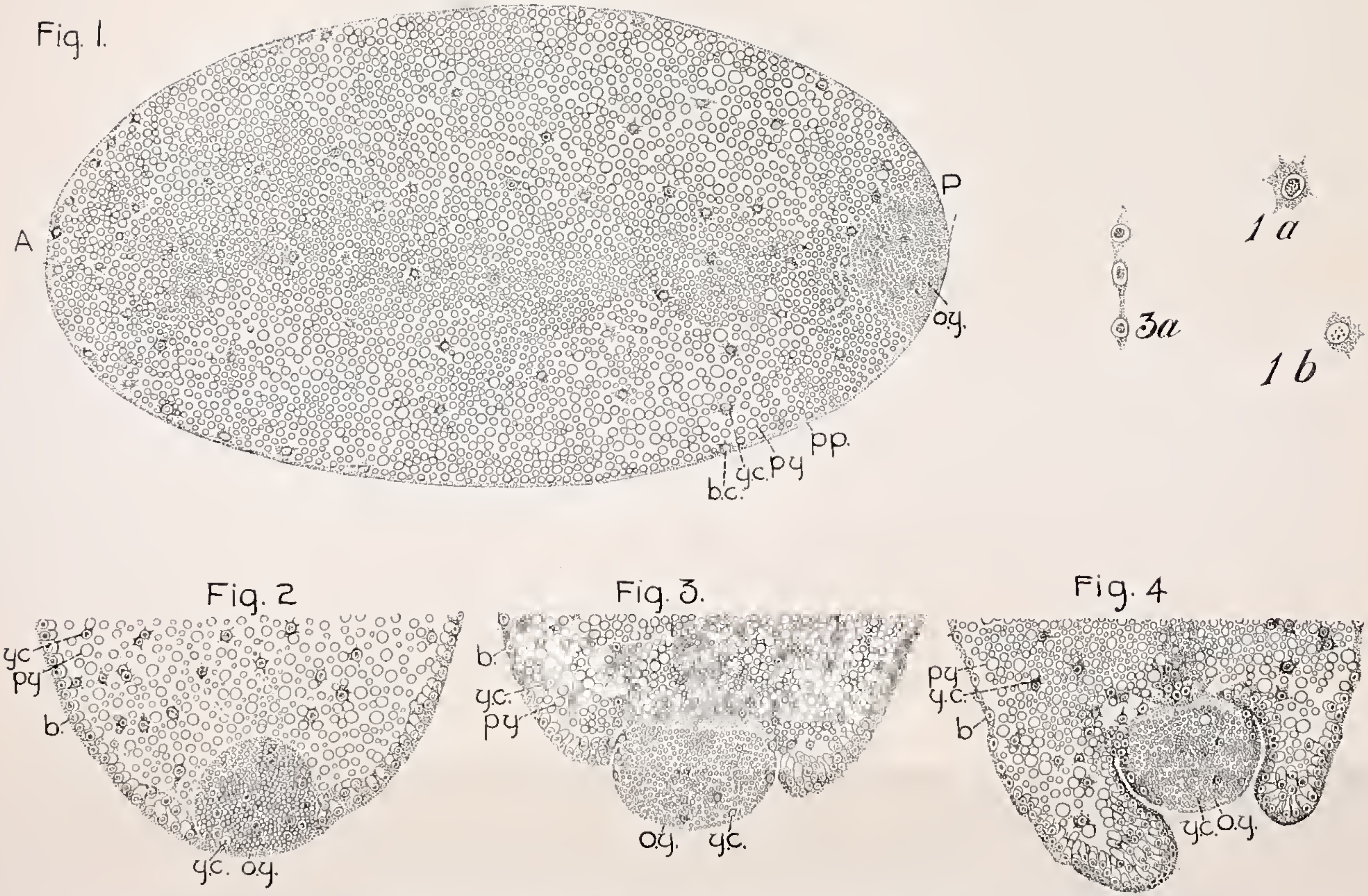
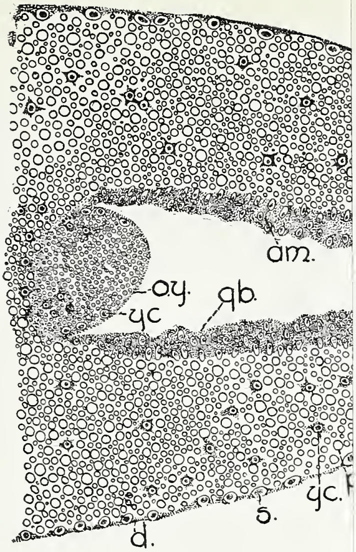


Fig. I.



DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.

Fig. 1.—Longitudinal section showing the blastoderm partly formed, being farthest advanced in the anterior region. The mass of ovarian yolk is lodged at the posterior pole. Figures 1*a* and 1*b* represent the yolk cells magnified 845 diameters. Fig. 2.—Longitudinal section showing the thickening of the blastoderm about the ovarian yolk previous to invagination. Magnified 156 diameters. Fig. 3.—Longitudinal section representing the germ band at the beginning of invagination, folding inward about the ovarian yolk. Magnified 156 diameters. Fig. 3*a*.—Section of the blastoderm. Magnified 430 diameters. Fig. 4.—Longitudinal section of a more advanced stage of invagination, the germ band having almost closed over the ovarian yolk. Magnified 156 diameters. (Original.)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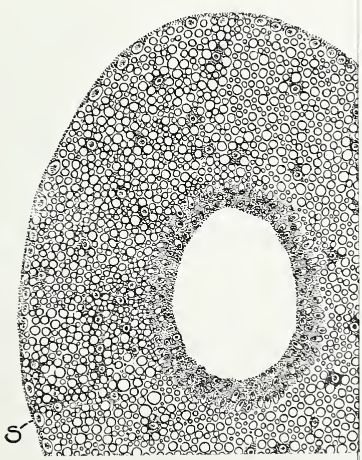
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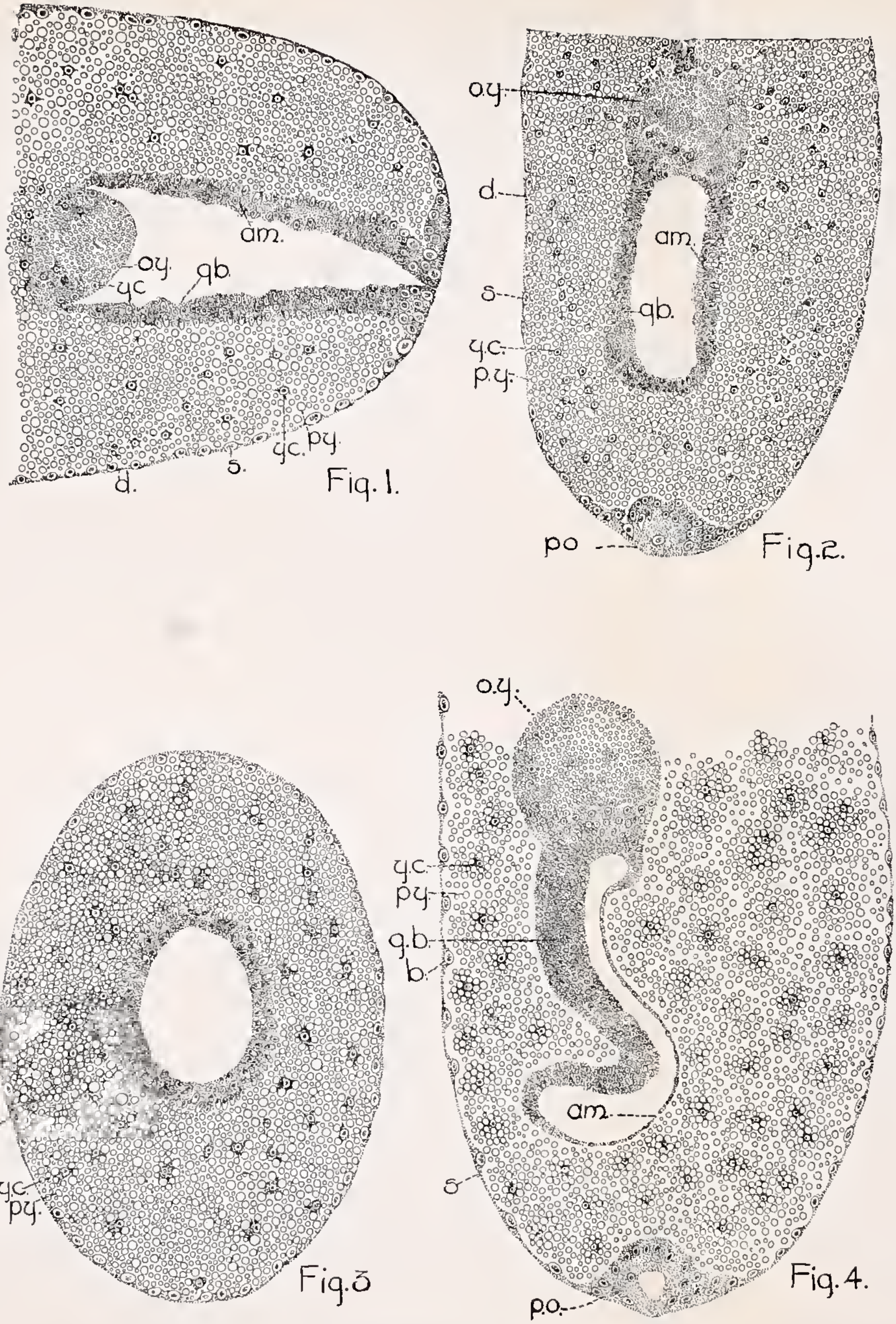


DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.

Fig. 1.—Longitudinal section representing the somewhat cone-shaped germ band ready to release itself from the surface of the egg, the ovarian yolk closing the posterior extremity. Magnified 156 diameters. Fig. 2.—Sagittal section representing the tubular germ band completely submerged within the yolk, the anterior extremity being continuous with the sides and the posterior end closed by the ovarian yolk. The "polar organ" is represented by a mass of cells and protoplasm at the posterior pole. Magnified 119 diameters. Fig. 3.—Transverse (somewhat oblique) section of the germ band. Magnified 156 diameters. Fig. 4.—Sagittal section showing the germ band folding and differentiating into amnion and germ band proper The ovarian yolk has taken a more anterior position. The "polar organ" is vacuolated now. Magnified 156 diameters. (Original.)

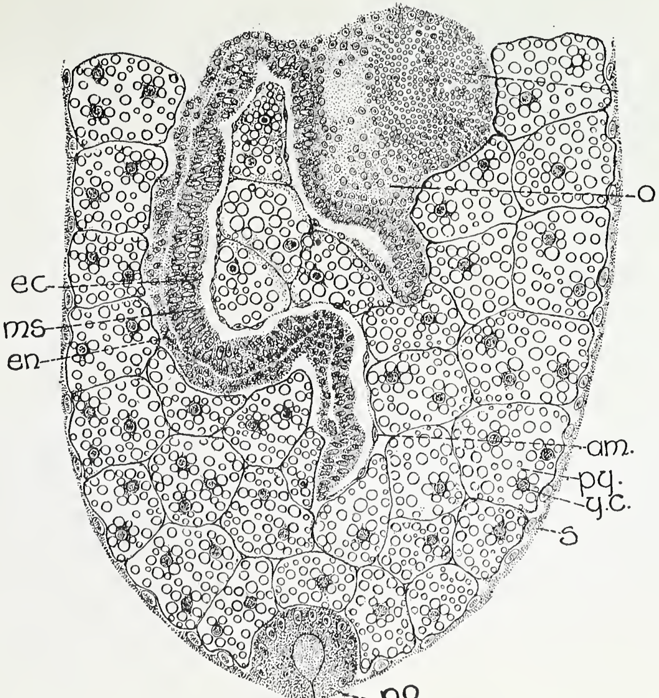


Fig. 1.

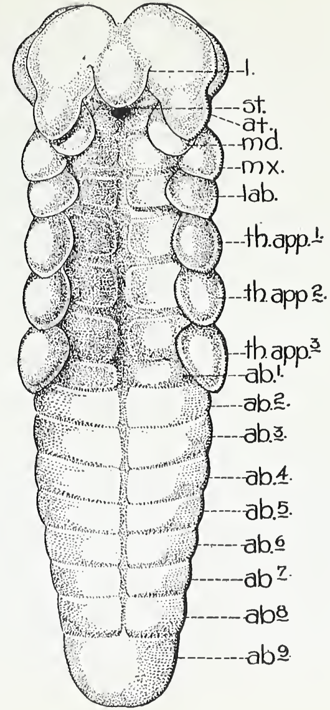


Fig. 2.

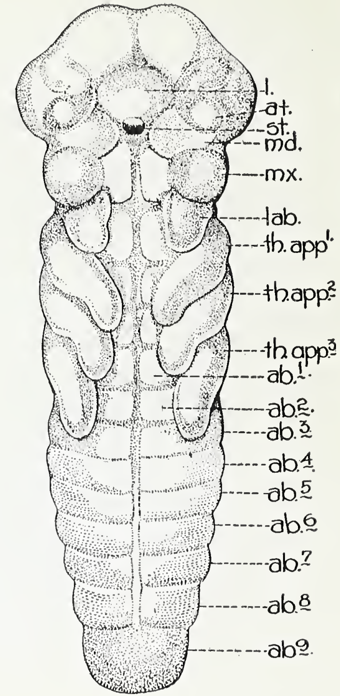
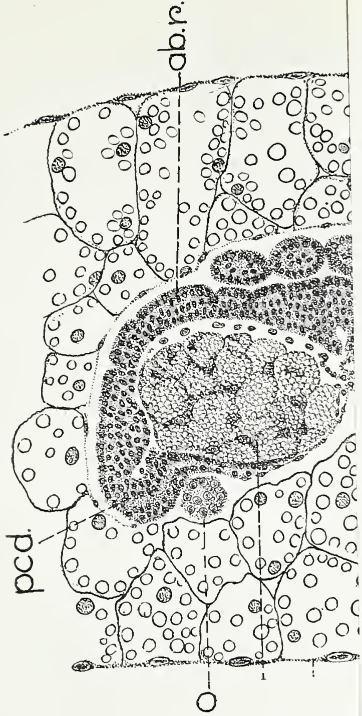


Fig. 3.

DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.

Fig. 1.—Sagittal section showing the germ band differentiated into three layers and folded almost upon itself, the ovarian yolk being separated from it by a group of cells that later becomes an ovary. The "polar organ" is now more nearly circular. Magnified 156 diameters. Fig. 2.—Surface view of Plate VI, figure 1. Magnified 156 diameters. Fig. 3.—Surface view of Plate VI, figure 2. Magnified 156 diameters. (Original.)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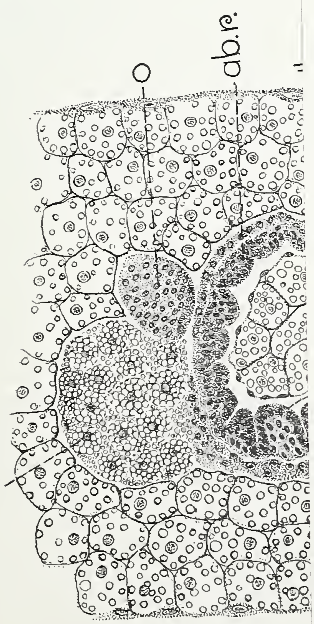
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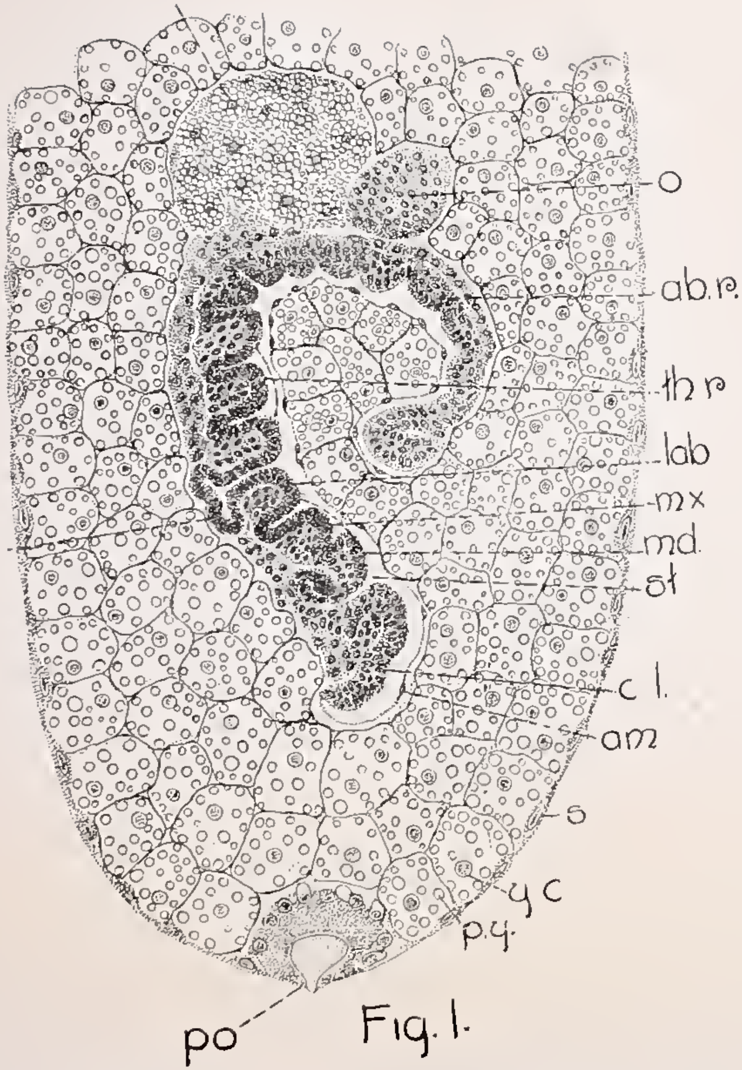

Fig. 1.

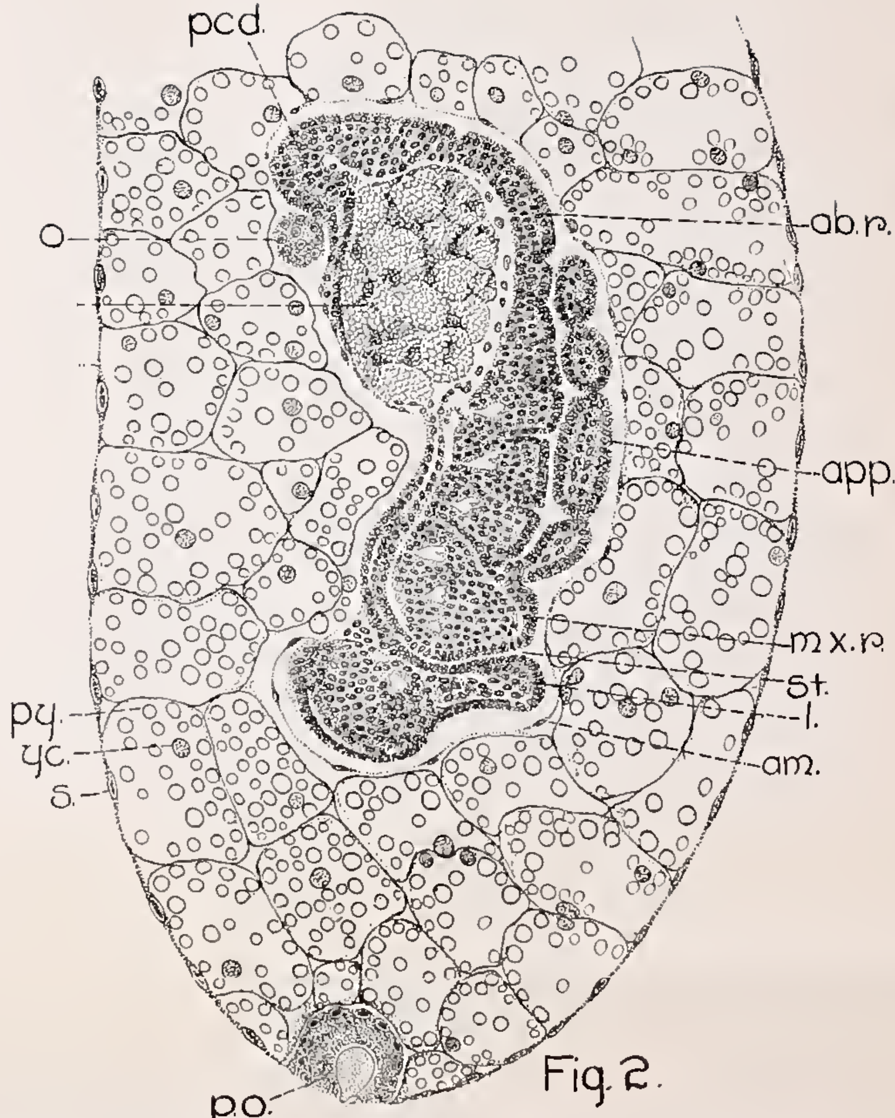

Fig. 2.

DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.

Fig. 1.—Sagittal section of the embryo showing the segmentation. The invagination of the salivary glands is now evident. The fundaments of the ovaries have assumed more definite shape and have shifted in position. The ovarian yolk is greatly changed in appearance and has taken up a position at the anterior portion of the abdominal region. The "polar organ" now shows a large, somewhat pear-shaped central cavity which opens upon the surface of the egg and is filled with a yellowish substance. Magnified 156 diameters. Fig. 2.—Sagittal section (slightly oblique) showing a much more advanced stage of growth than that of figure 1, the abdominal region having reversed its position by bending around backward and inclosing the ovarian yolk. The mesenteron is in process of formation. The ovarian yolk is granular and its cells are breaking down. The "polar organ" is much the same as in the preceding stage. Magnified 156 diameters. (Original.)

In *Stage 8* (Pl. VI, fig. 2) the posterior or abdominal region of the embryo has now completely changed its position, having folded back dorsally about the ovarian yolk. Plate VI, figure 2, shows a sagittal (slightly oblique) section of an embryo at this stage. There are apparently only 9 abdominal segments. Both the stomodæum and the proctodæum are plainly in evidence now, and the mesenteron is in course of formation. The latter is formed above and rests upon the ovarian yolk. This yolk now has a granular appearance, and the yolk cells within it appear to be breaking down. It is still divided off into subspherical masses. The polar organ is smaller than in the preceding stage and the pear-shaped area in the center is filled with a yellowish substance as before. The ovaries are represented in this section by a circular mass of cells above the ovarian yolk. The primary yolk is grouped and divided off by protoplasmic threads, very much as in the preceding stage, but is not quite so abundant now. Plate V, figure 3, shows a surface view of the embryo, straightened out to its full length. It will be seen that the appendages are now much more elongate, the thoracic appendages showing traces of segmentation. All the appendages are now directed posteriorly and lie flat upon the body.

This is the stage in which the majority of the embryos pass the winter. It is very doubtful if any of the stages earlier than the seventh are able to survive the winter. Instances have come under our observation in which embryos in the sixth stage have been killed by very low temperatures. When heavy freezes do not occur until sometime in December, a very large percentage of the eggs hatches; on the other hand, however, when heavy freezes begin in November, large numbers of the eggs are killed in the early stages, since large numbers of the eggs are deposited in this month. An early autumn, therefore, followed by a severe winter, would limit to a great extent the number of stem mothers of the following spring.

Stage 9 (Pl. VII, figs. 1–4) represents the stages of growth occurring in the latter part of February and the first of March. When the embryo is ready to come to the surface of the egg (Pl. VII, fig. 1), it moves forward in the yolk until the cephalic lobes come into contact with the polar organ. It will be observed that there is quite a gap between figures 1 and 2, and at present we have no material from which this missing link can be supplied. Figure 2 shows the dorsal organ already formed. As we have no intermediate stages we can not state definitely whether this is the true dorsal organ or the dorsal and polar organ combined. It is probably the latter, as we do not find any traces of the polar organ at any other point in the embryo. It is very probable that the surplus cells of the serosa, at the time the embryo comes to the surface of the egg, collect at and group themselves about the polar organ, as there

appear to be a greater number of cells about this body at this time. There is no trace of the dense yellowish center of the polar organ, otherwise it resembles this body very closely. However, as we have lost track of this organ in the gap between figures 1 and 2, and on account of the close resemblance between it and the dorsal organ of other insects, we have designated it as the latter. At a later stage (Pl. VII, fig. 3) the dorsal organ has assumed a more nearly circular shape, the mouth having almost closed, inclosing a somewhat pear-shaped space. At a still later stage (fig. 4) the dorsal organ has released itself from the margin, migrated backward, and begun to disintegrate. At length it disappears by absorption in the body cavity.

At first we were not able to note a revolution of the embryo, but later studies show that such a revolution does occur between figures 1 and 2 of Plate VII.

After the ninth stage the development goes on very rapidly, and by the latter part of March the eggs are ready to hatch.

During the fall of 1909 a number of eggs were collected that had been deposited in October and November, and these were kept until the spring of 1910 to note the time of hatching. No heavy freezes occurred until the 3d of December. It was found that although there was nearly a month's difference in dates of deposition there was not more than four or five days' difference in the time of hatching. An average of 64 per cent of the eggs hatched. We have also learned that eggs will not hatch unless subjected to freezing temperatures.

SUMMARY OF EMBRYOLOGICAL DEVELOPMENT.

There is a large almost circular mass of ovarian yolk at the posterior pole of the egg.

Development begins almost immediately after oviposition, and proceeds more rapidly in the region of the anterior pole until after the blastoderm forms, after which growth almost ceases in this region.

The blastoderm originates through the migration of yolk cells from the interior to the surface of the egg. All of the yolk cells, however, do not take part in the formation of the blastoderm, part remaining behind to prepare the yolk for assimilation by the embryo.

After the blastoderm is formed it is one cell thick and covers the entire surface of the egg, with the exception of the ovarian yolk. The germ band originates in the region of the ovarian yolk, where it invaginates and grows downward into the egg. The germ band is of the completely submerged type, the uninvaginated blastoderm becoming the serosa.

Upon leaving the surface of the egg the germ band leaves behind it a group of cells embedded in a mass of protoplasm. This body the junior author has termed the "polar organ."

The development of the embryo can be observed in a general way, with a hand lens, up to and including the sixth stage. This stage is reached, under favorable weather conditions (50° to 75° F.), in about three days.

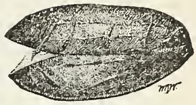

FIG. 18.—The spring grain-aphis: Shell of egg after young stem-mother has emerged. Greatly enlarged. (Original.)

A large number of embryos are nearly or quite half grown by the time freezing weather begins, growth starting again with the first warm days of February. We have noted a revolution of the embryo within the egg, and this revolution takes place between figures 1 and 2 of Plate VII. Eggs begin to hatch by the last week in March, the typical appearance of the abandoned eggshell being shown in text figure 18. The number of stem mothers to appear in spring depends to a large extent upon the temperature of the preceding fall.

ABBREVIATIONS USED IN PLATES III–VII.

A., anterior pole.
ab^1, *ab*^{2}, etc., abdominal segments.
ab. r. abdominal region.
am., amnion.
app., appendage.
at., antenna.
b. c., blastoderm cell.
b., blastoderm.
c. l., cephalic lobes.
d. o., dorsal organ.
ec., ectoderm.
en., entoderm.
g. b., germ band.
l., labrum.
lab., labium.
md., mandible.
ms., mesoderm.
mx., maxilla.
o., fundament of ovary.
o. y., ovarian yolk,
p., posterior pole.
p. o., "polar organ."
p. p., peripheral protoplasm.
p. y., primary yolk.
pcd., proctodæum.
s., serosa.
s. g., salivary gland.
st., stomodæum.
th. app^1, ^{2}, etc.,thoracic appendages.
th. r., thoracic region.
y. c., yolk cells.

NATURAL ENEMIES.

Toxoptera graminum is beset by a host of foes, without which we would be powerless to combat it. These enemies naturally group themselves into two classes: First, insects that develop within the body of the "green bug" and are termed true parasites; secondly, those foes that feed upon them externally or that take them directly into their bodies. These latter are termed predatory enemies. Under the true parasites we have *Aphidius testaceipes* Cress., *Aphidius avenaphis* Fitch, *Aphidius confusus* Ashm., *Aphelinus mali* Hald., *Aphelinus nigritus* How., and *Aphelinus semiflavus* How., all of which are minute four-winged flies; under predatory enemies there are lady-beetles, syrphids, and cecidomyiids (two-winged flies), lacewing flies, and birds. Besides these, there are *secondary* parasites, or those that prey upon the true parasites of Toxoptera. These latter are as truly our enemies as are Toxoptera.

INTERNAL OR TRUE PARASITES.

Aphidius testaceipes Cress.

(Fig. 19.)

Synonyms: *Lysiphlebus abutilaphidis* Ashm.; *Lysiphlebus baccharaphidis* Ashm.; *Lysiphlebus basilaris* Prov.; *Lysiphlebus citraphis* Ashm.; *Lysiphlebus coquilletti* Ashm.; *Lysiphlebus cucurbitaphidis* Ashm.; *Lysiphlebus crawfordi* Rohwer; *Lysiphlebus eragrostaphidis* Ashm.; *Lysiphlebus gossypii* Ashm.; *Lysiphlebus myzi* Ashm.; *Lysiphlebus minutus* Ashm.; *Lysiphlebus persicaphidis* Ashm. (=*L. persiaphidis* Ashm.); *Lysiphlebus piceiventris* Ashm.; *Lysiphlebus tritici* Ashm.

DESCRIPTION AND IDENTITY.

Female.—Piceous or shining black, smooth and polished, impunctured; mandibles and palpi pale; antennæ brownish-black, sometimes more or less pale beneath,

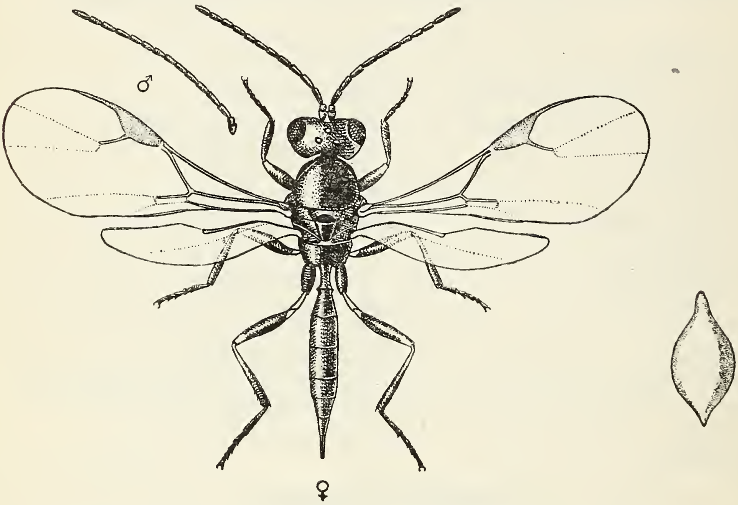

FIG. 19.—*Aphidius testaceipes*, principal parasite of the spring grain-aphis: Adult female and antenna of male, greatly enlarged. Egg at right, highly magnified. (From Webster.)

13-jointed, the joints faintly fluted or grooved, the last one longest and thickest; wings hyaline, iridescent, stigma pale; legs, including coxæ, yellowish-testaceous, the posterior pair generally more or less fuscous or blackish; abdomen often brown or pale piceous, with the first and sometimes part of the second segment more or less testaceous. Length, 0.07 inch.

Habitat.—Rockledge, Fla.; Selma, Ala.; and Pocomoke City, Md.

Parasitic upon an aphidid infesting twigs of orange, an aphidid on the cotton plant, and *Aphis avenæ* Fab.

This parasite, which is probably the most important of all the natural enemies of Toxoptera, has for this reason claimed more of our attention than all of the other foes combined. Hence a large amount of data has been collected, bearing upon nearly every phase of its development. Owing to the fact that large numbers of individuals have been reared by Messrs. Kelly and Urbahns from known par-

ents, both parent and offspring being preserved, Mr. H. L. Viereck, of this bureau, has been able to determine definitely for us the identity of this species and to clear up the obscurity heretofore surrounding it. He finds that it has been masquerading under 14 different names, and it seems that it may now be allowed to assume its rightful designation.

Mr. Viereck, after a careful study of all material at hand, has supplied us with the above list of synonyms. His work on the revision of the genera Aphidius, Lysiphlebus, and Diæretus will appear later in some other publication.

LIFE HISTORY.

OVIPOSITION.

Under favorable conditions the females begin ovipositing within a few hours after issuing, whether a male is present or not. When the female is placed in the presence of Toxoptera she will rush about

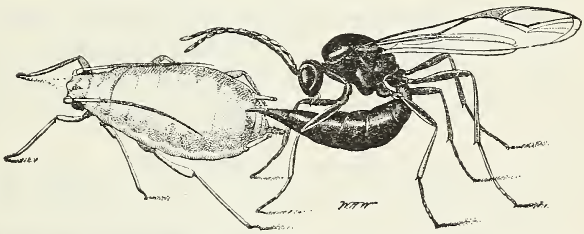

FIG. 20.—*Aphidius testaceipes* ovipositing in the body of the spring grain-aphis. Enlarged. (From Webster.)

in an excited manner and when her antennæ come in contact with an aphis she stops very quickly and thrusts her abdomen beneath her thorax and head (see fig. 20), giving the aphis a quick stab—sometimes several if the first attempts were unsuccessful; she oftentimes lifts the smaller plant-lice completely from the leaf, they are stabbed so fiercely. The act of oviposition shown in the illustration is not intended to convey the impression that the Aphidius always attacks the grain aphis at this point, as it will stab it from any position; it will oftentimes reach around the margin of a leaf and pierce an aphis on the opposite side. After being stung the aphidids kick up the posterior part of the abdomen as though in pain, and sometimes a tiny drop of fluid will appear at the tip of the cornicles. At no stage do the aphidids appear to be exempt from attack. The Aphidius readily attacks the winged, but apparently prefers the wingless forms.

If parasites are confined with plant-lice for quite a while they will stab them repeatedly, though we have never reared more than one individual from the body of an aphis. It is very probable that in cases of this kind it is the survival of the fittest, the strongest Aphidius larva devouring all of the others. The junior author and Mr. W. R.

Walton, of this bureau, observed a larva, taken from the body of a "green bug," to apparently feed upon another larva of the same species that was resting against it. This would seem to indicate a tendency toward cannibalism. The parasites have been observed apparently ovipositing in aphidids that were already dead from parasitic attacks, those killed by fungus, and sometimes even puncturing the leaves of the plants on which Toxoptera were located.

The period of oviposition varies from 3 days to a week or more, depending upon the temperature. In warm weather the females will easily live and oviposit for 5 or 6 days.

LENGTH OF PERIOD FROM EGG TO ADULT.

Messrs. Kelly and Urbahns found that at Wellington, Kans., from 7 to 15 days are consumed in passing from egg to adult during August and September, while for October and the first week in November it requires from 8 to 24 days. These figures are to a slight degree artificial, as the rearings upon which they are based were conducted indoors. The room was heated by a stove, during the day only, for a part of October and November, and all fire was extinguished at night, so that the temperature at night probably went almost as low as out of doors, the house being only a small two-room structure.

The average for August and September is 11.1 days; the average for October and November (first week) is 19 days, the average for the whole period being 15.9 days. These averages were made up from observations on 116 individuals and are therefore of more value than they would be if made from a few individuals only.

At Richmond, Ind., the period from egg to adult out of doors varies from 10 to 14 days during August and September, while Toxoptera that were parasitized during November of 1907 and kept out of doors did not give up adults until the 27th and 28th of March and the 4th of April, 1908, a period of over 4 months.

EFFECT OF PARASITISM BY APHIDIUS UPON DEVELOPMENT OF HOST.

It has been found, as previously stated, that at no time from birth to and including the adult stage is Toxoptera exempt from attack by Aphidius. It appears that a female Aphidius prefers to oviposit in Toxoptera of the second and third instars. The parasite apparently shows little or no fear of them at this stage, while if she is among a number of adult Toxoptera and they begin to kick up their abdomens, she often hurries away, apparently in alarm.

It appears from our observations that Toxoptera stung before the first or second molt will not reach maturity, nor will the developing parasite become adult, there being apparently insuffcent nourishment contained in such small individuals. Aphidids parasitized after

the second molt will become adult, but may be either winged or wingless; the wings in such cases often being imperfect. Oftentimes parasitized aphidids reach the third molt, but do not become adult before death, though the parasite reaches maturity, and it is probable that such Toxoptera were parasitized just before casting the second molt. This may also account for some of the small individuals among the parasites.

EFFECT OF PARASITISM BY APHIDIUS UPON FECUNDITY OF HOST.

Experiments have been conducted with the view of learning the number of young that may be produced after parasitization. This can probably be best illustrated by Table XII.

TABLE XII.—*Effect, on fecundity of Toxoptera graminum, of parasitization by Aphidius testaceipes.*

Number of individuals.	Stage when parasitized.	Date parasitized.	Kind of adult.	Daily number young.										Total young.	Date aphis died.
				Oct. 15.	Oct. 16.	Oct. 17.	Oct. 18.	Oct. 19.	Oct. 20.	Oct. 21.	Oct. 22.	Oct. 23.	Oct. 24.		
1	Fourth instar	Oct. 15	Winged		A.			6						6	Oct. 24
1	do	Oct. 16	do			A.	6	3						9	Do.
1	Wingless adult	do	Wingless				2	3	1					6	Do.
1	do	do	do				4	4	2					10	Oct. 27
1	do	do	do			2	1	2						5	Oct. 20

Number of individuals.	Stage when parasitized.	Date parasitized.	Kind of adult.	Daily number young.										Total young.	Date aphis died.
				Mar. 15.	Mar. 16.	Mar. 17.	Mar. 18.	Mar. 19.	Mar. 20.	Mar. 21.	Mar. 22.	Mar. 23.	Mar. 24.		
1	Fourth instar	Mar. 17	Winged						A.	2				2	Mar. 25
1	do	do	do						A.	4				4	Do.
1	do	do	do				A.		6	2				8	Do.
2	do	do	do						A4	7				11	Do.
2	do	do	do						A1	10	3			14	Do.
6	do	do	do						A1	A16	9			26	Do.
9	Winged	do	do				1		38	21	2			61	Mar. 26
4	Fourth instar	do	Wingless				A.		A9	34				43	Do.
5	Third instar	do	Winged				M.		M1		A2			3	Do.

A.=Adult. M.=Molt.

Two adult Aphidius issued from those individuals included in the first section of the table and 18 from those in the last section. In this latter section Aphidius began to issue March 30 and the last issued on April 3. Those that issued on the latter date were from those that were adult winged adults when parasitized.

All of these experiments were conducted indoors, and those of the last division of Table XII, under a daily temperature ranging from 50° to 80° F.

From Table XII it will be seen that Toxoptera that have molted only twice before being parasitized may become winged adults, and in some instances produce young. All of our observations show that individuals that have molted three times and then been parasitized will become adult and produce young, and in case they are wingless they may produce 10 or more. Eleven is the maximum number of young, according to our observations, produced by a single individual after parasitization.

MOVEMENT OF LARVA WITHIN THE HOST AND MANNER OF ATTACHING IT TO THE PLANT.

Observations were made upon the movements of the larva (fig. 21) within the host by the senior author at Manhattan, Kans., in 1907, and published in the Proceedings of the Entomological Society of Washington.[1]

It appears that the larva of the parasite, at least until after it attains some growth, moves little if at all within the body of the host, and thus interferes with no vital functions of the Toxoptera.

When the larva nears maturity, as shown by the yellowish color of the abdomen of the "green bug," it becomes quite active, making a number of revolutions within the body of its host, at which time the latter seizes the leaf with a rigid death-grip and the last spark of life soon fades. The object of the revolutions is, apparently, to mold the body wall of the aphidid, while it is still plastic, into the most suitable shape for pupation. An idea of how this desired end is accomplished may be obtained by glancing at the accompanying illustrations. Figure 22 shows the normal position of the parasitic larva within the body of the host before the revolutions begin. It was found that a fully developed larva (fig. 23) made three revolutions within the body of the host, always going forward, in the space of 35 minutes. During the next 5 minutes it made another revolution; a fifth revolution was completed in the next 10 minutes; the sixth during the following 8 minutes; the seventh in the next 9 minutes; the eighth after a space of 4 minutes; the ninth in the following 4 minutes, after which, on account of the opaqueness of the walls of the host, no further count was kept of the revolutions, although several more were known to have been made. Some of these different positions of the larva and

[1] Proc. Ent. Soc. Wash., vol. 9, Nos. 1-4, pp. 110-114, 1907.

the shapes the body of the Toxoptera assumes are graphically represented in figure 21. At this time, or about one and one-half hours

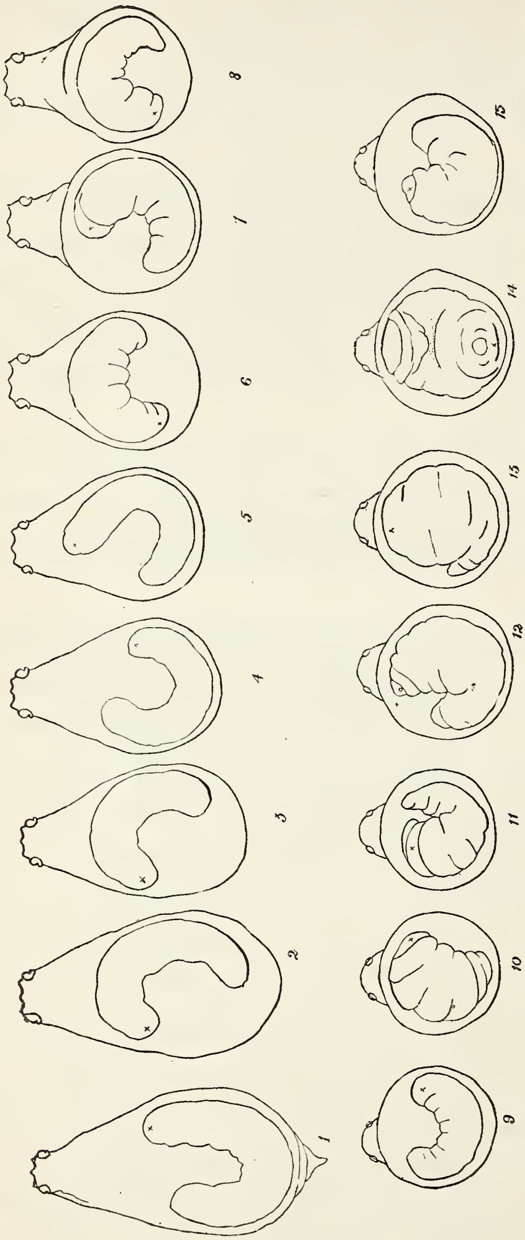

FIG. 21.—(1) Position of larva of *Aphidius testaceipes* in body of wingless adult female of the spring grain-aphis, just before beginning its revolutions for fashioning the body of the aphis into a pupal envelope, 11 a. m. (2–7) Some of the positions assumed by the Aphidius larva between 11 a. m. and 11.35 a. m., during which time it made three complete revolutions. (8–9) Positions during and at completion of eighth revolution, 12.11 p. m. (10) Position at completion of ninth revolution, showing contraction of the larva, 12.15 p. m. (11) Position at 12.20 p. m. (12) Position at 12.22 p. m. (13) Position at 12.27 p. m. (14) Position at 12.32 p. m. (15) Position at 12.32½ p. m. (From Webster.)

after the observations were begun, the body wall of the "green bug" became quite dark and almost globular in form, and this shape it afterwards retained.

Mr. Kelly, of this bureau, later took up the observations at this point, during the fall of 1908, and published the results of his obser-

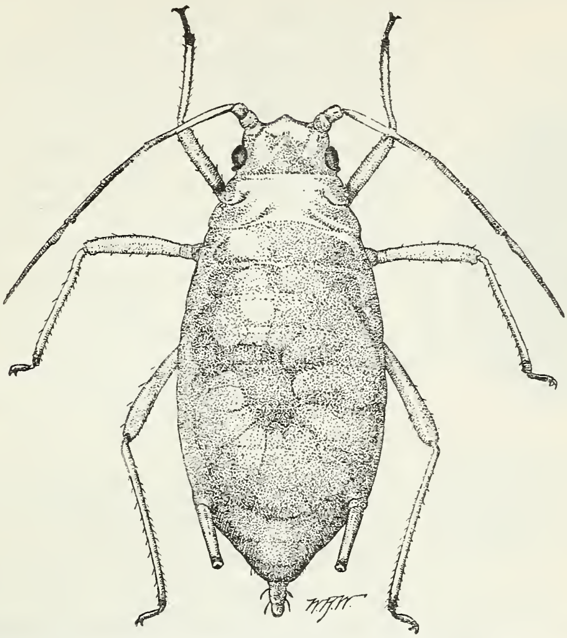

FIG. 22.—Position of larva of *Aphidius testaceipes* in the body of the spring grain-aphis at the beginning of the change to a yellowish color. Much enlarged. (Original.)

vations in the Proceedings of the Entomological Society of Washington.[1] Mr. Kelly confined some aphidids that were nearly dead from parasite attack on a slide and observed them under the microscope. He found that as the body of the "green bug" takes on a brownish tint, the Aphidius larva within makes a longitudinal slit or opening in the ventrum and enlarges it until it is more or less oval in shape, as shown in figure 24.

FIG. 23.—Full-grown larva of *Aphidius testaceipes* taken from body of the spring grain-aphis as shown in figure 22. Much enlarged. (Original.)

The rigid, firm manner in which Toxoptera grasps the object upon which it is resting at death apparently has the effect of holding it in place while the movements of the parasitic larva are going on within. When the opening is complete the larva begins to spin its cocoon, at the same time ejecting a glutinous fluid that makes the strands adhere to any object

[1] Proc. Ent. Soc. Wash., vol. 11, No. 2, pp. 64–66, 1909.

with which they come in contact. The body of the aphidid is cemented firmly to the object upon which it finally comes to rest. The inner abdominal walls of the plant-louse are also lined with silk, which firmly adheres to them, and it may be that the silk also acts as a tanning substance for the body of the aphidid, as the latter becomes leathery and is apparently impervious to water; the old leathery bodies of the plant-lice may often be found firmly attached to plants after a heavy rain. After the cocoon is completed the larva becomes quiet and in most cases assumes, according to the junior author, a position directly opposite to that which it assumed while feeding and developing. Figure 22 shows a larva feeding, however, in the reversed position; this seems to be unusual, the normal position being as shown in Figure 21, *l*. The larva oftentimes, on becoming fully developed, is in some way dislodged from the body of the aphidid. This is probably due to some interference while attaching the host to the leaf. These cases are quite numerous in badly infested fields and the larvæ apparently never become adult. Figure 25 is a graphic illustration of one of these accidents.

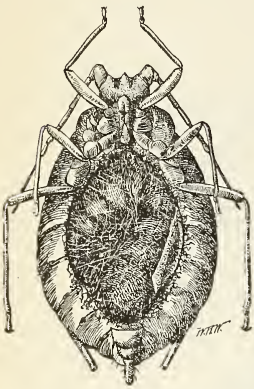

FIG. 24.—Larva of *Aphidius testaceipes* spinning its cocoon in the dead body of the spring grain-aphis, showing the slit or opening in walls of underside of host insect. Much enlarged. (Original.)

Mr. Kelly found that the pupal stage lasted from 3 to 4 days.

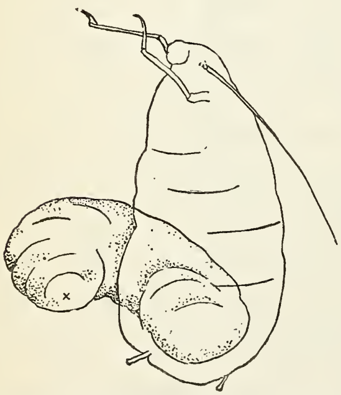

FIG. 25.—Larva of *Aphidius testaceipes* working its way prematurely from the body of the spring grain-aphis. (From Webster.)

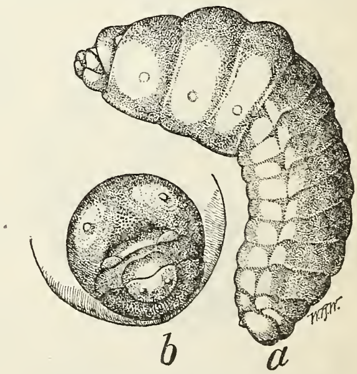

FIG. 26.—Full-grown larva of *Aphidius testaceipes*: *a*, Lateral view just prior to pupation; *b*, front view of head. Greatly enlarged. (Original.)

Figure 26 shows the larva just prior to pupation. These observations were made indoors, during the winter, at the ordinary room temperature. It requires from 3 to 5 hours for the Aphidius to

emerge as an adult after the first movements of the pupa begin, and when ready to issue the pupa expands and contracts the abdomen, moving the feet and antennæ until these are freed from their gum-like covering. Upon studying the pupæ (fig. 27) closely, we find that the prothorax bears two rows of distinct elevations or tubercles, but we have been unable thus far to ascribe any particular function to them and they disappear with the gum-like covering. The junior author finds that the adult gradually works itself about until it gets in a position with its back to the ventrum of the old aphidid shell, when it cuts a circular hole, as described by Mr. Kelly, and crawls out, always with its head pointing toward the head of the old aphidid. Figure 28 represents an old dead body of a "green bug" after the parasite has issued.

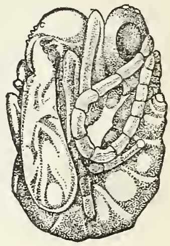

FIG. 27.—Pupa of *Aphidius testaceipes* immediately after pupation. Much enlarged. (Original.)

FECUNDITY.

From the prompt manner in which Aphidius, under favorable weather conditions, overcomes Toxoptera it will readily be seen that the former must be a very prolific breeder. The average adult female contains from 4 to 450 eggs. These eggs are lemon-shaped (see fig. 19), very pale, and translucent.

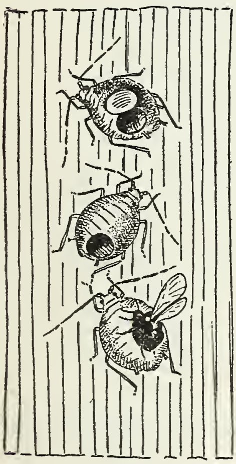

FIG. 28.—Dead "green bugs" (*Toxoptera graminum*), showing holes from which the matured parasites of *Aphidius testaceipes* emerge. The top figure shows the lid still attached, but pushed back; the bottom figure shows the parasite emerging. Enlarged. (From Webster.)

Messrs. Kelly and Urbahns conducted a number of experiments at Wellington, Kans., in 1908, to determine the number of offspring produced by one individual. They found that one Aphidius would parasitize as many as 206 Toxoptera. In their experiments, however, they used only a few more than 200 Toxoptera to each individual. Mr. Parks, at the same place in 1909, conducted 16 experiments, using from 300 to 500 Toxoptera and he had a maximum, in one case, of 301 aphidids parasitized from one individual Aphidius. His minimum was 3; his next highest number was 33, and his next was 44. Of the sixteen, 12 fell below 100; his average was 94.6.

Mr. Parks also conducted experiments at the same time as the above to ascertain what the effects of continuous mating of one male to different females would have on the offspring. In this experiment 1 male was mated to 12 unfertilized females within a period of two hours, after which each female was placed in a separate cage with about 100 Toxoptera that had not been exposed to Aphidius.

The male refused to mate with any more females after the twelfth. Table XIII shows the results of these observations:

TABLE XIII.—*Offspring produced as the result of mating one male Aphidius with 12 females.*

Female, cage No.—	Female mated with male from cage No.—	Offspring.	
		Males.	Females.
180	180	29	55
181	180	14	33
182	180	21	30
183	180	35	41
184	180	2	8
185	180	0	0
186	180	13	30
187	180	39	25
188	180	1	0
189	180	50	0
190	180	8	9
191	180	26	16

From these data it appears that all of the eggs from the last few females were not fertilized, as Mr. Kelly finds that females predominate when the eggs are properly fertilized. Table XIV illustrates this latter point.

TABLE XIV.—*Offspring of Aphidius produced from eggs properly fertilized.*

Cage No.—	Offspring.	
	Males.	Females.
197	39	67
297	15	20
299	13	33
300	24	40
302	20	34
304	16	50
306	47	[1] 2
333	115	[1] 5
403	26	41
404	38	93
405	26	44
Total ..	379	429

[1] These two females were apparently unfertilized, although they were supposed to have mated, as they give about the same results as some of the unmated females. If these two be eliminated it will be seen that the females are far in excess of the males.

PARTHENOGENESIS.

In all of the studies of parthenogenesis care was taken to preserve both parents and offspring, the individuals of each family or brood being preserved and kept entirely separate for future systematic studies, which were later carried out by Mr. Viereck.

The first record of parthenogenesis of this species was published in the Proceedings of the Entomological Society of Washington,[1] by the junior author, whose attention was first called to this phenomenon

[1] Proc. Ent. Soc. Wash., vol. 10, Nos. 1-2, September 15, 1908, pp. 11-13.

during the summer of 1907, while making observations on the life history of the species; hence, a series of experiments was begun in order to learn something definite in regard to it. Seven female Aphidius were selected, just as they issued from their cocoons (being therefore unfertilized), and placed in separate cages with 30 to 40 Toxoptera not previously exposed to parasite attack. All of the parasites began ovipositing at once. After one of the females had apparently parasitized all of the aphidids in her cage she was mated and placed in a second cage with a number of Toxoptera as before. All the offspring from unmated females were males, but the offspring from the single female, *after she had mated*, comprised 22 females and 4 males.

Messrs. Kelly and Urbahns elucidated this phenomenon more fully during the summer of 1908 at Wellington, Kans.[1] These experiments were conducted as follows:

Starting with a mated female, the females from among her offspring were isolated, even before emergence. On their appearance they were given Toxoptera not previously exposed to parasitic attack. The few females from among this second generation were again isolated in the same manner, the females in all cases being kept unmated. Nearly 100 experiments were conducted in this manner, but only 48 gave results. The offspring of 44 out of the 48 isolated were, all of them, males. Of the 4 remaining females, the offspring of 3 were as follows: 70 males and 3 females; 101 males and 6 females; 67 males and 1 female. In the case of the remaining female, some uncertainty exists as to whether she had been fertilized or not, and, for this reason, a census of her offspring is not here included.

Of the three exceptional cases the offspring from one female were not bred any further; from a second, the offspring became all males in the second generation; the offspring from the third female produced two females in the second generation, all finally becoming males in the third generation.

In this manner it will be seen that Messrs. Kelly and Urbahns were able to rear a limited number of females parthenogenetically to the third generation. Beyond this all of the offspring were males. While the conditions under which these experiments were conducted would not obtain under ordinary field conditions where the infestation was great, it could very easily occur where there are very few aphidids present. This apparently abnormal feature, then, would greatly assist the species in tiding over periods of scarcity of plant-lice.

HOSTS OF APHIDIUS TESTACEIPES.

Since we were able to find *Aphidius testaceipes* over almost the entire United States, it seemed clear to us that it must have hosts other than *Toxoptera graminum*. Accordingly Messrs. Kelly and Urbahns con-

[1] Ann. Ent. Soc. Amer., vol. 2, No. 2, 1909, pp. 67–87.

ducted about 200 experiments in order to gain some definite information on this point. Their mode of procedure was to search out different species of parasitized aphidids in the fields, rear the adult parasites, and breed them into *Toxoptera graminum;* then, if possible, breeding them again into the original host. One attempt, if unsuccessful, was not considered sufficient, several trials being made. While conducting these experiments, other species of parasites were found that would breed into Toxoptera also. These will be dealt with in their proper places. In all of these breedings, both parent and offspring were kept separate and preserved for future study.

It was found that *Aphidius testaceipes* would breed interchangeably from Toxoptera into *Aphis setariæ, Aphis maidis, Aphis middletoni* Thos.,[1] *Aphis gossypii,* and a species of Chaitophorus. This is the same as the list published by the senior author in the Annals of the Entomological Society of America,[2] with the exception that Chaitophorus is added and *Aphis brassicæ* has been expunged from the list, as it has been learned that the species of parasite that would interchange with *Toxoptera graminum* and *A. brassicæ* is another species of Aphidius.

Besides the above list of interchangeable breedings, *Aphidius testaceipes* has been reared from *Aphis œnotheræ* at Salisbury, N. C., by Mr. R. A. Vickery; from *A. medicaginis* at Wellington, Kans., by Messrs. Kelly and Urbahns; from *A. rumicis* at Clemson, S. C., by Mr. G. G. Ainslie; from *Macrosiphum viticola* at Wellington, Kans., by Mr. Kelly; from *M. granaria* at Spartanburg, S. C., by Mr. G. G. Ainslie; from *Melanoxantherium* sp. at Leavenworth, Kans., by Mr. Kelly; from *Macrosiphum* sp. on black gum (*Nyssa sylvatica*) at Salisbury, S. C., by Mr. Vickery; from *Aphis avenæ,* at Salisbury, N. C., by Mr. Vickery; at Leavenworth, Kans., by Mr. Kelly, and at Washington, D. C., by Mr. C. N. Ainslie; and from *Aphis medicaginis* by Mr. J. T. Monell, at St. Louis, Mo. *Aphidius testaceipes* has also been reared from several unidentified species of aphidids, as follows: From an aphidid on *Ampelopsis* sp. by Mr. C. N. Ainslie; from an aphidid on *Capsella* sp. at Wellington, Kans., by Mr. C. N. Ainslie; from an aphidid on *Kochia scoparia* at Rochester, Minn., by Mr. C. N. Ainslie; from an aphidid on locust at Wellington, Kans., by Mr. Kelly; from an aphidid on plum at Salisbury, N. C., by Mr. Vickery; from an aphidid on pigweed (*Chenopodium album*) in Olmstead County, Minn., by Mr. C. N. Ainslie.

Further addition to this list of hosts may be made by citing the hosts of some of the synonyms of *Aphidius testaceipes.*[3] We will deal

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[1] *Aphis middletoni* can not be satisfactorily separated from *Aphis maidi-radicis* and when found on any other plant except Erigeron it has usually been identified as *Aphis maidi-radicis.* (See Bul. 85, Bur. Ent., U. S. Dept. Agr., pp. 113–114. Contributions to a Knowledge of the Corn Root-Aphis, by R. A. Vickery.)

[2] Ann. Ent. Soc. Amer., vol. 2, No. 2, pp. 67–87, June, 1909.

[3] See Proc. U. S. Nat. Mus., vol. 11, pp. 665–669, 1888.

with these synonyms collectively under *A. testaceipes*. The hosts then would be as follows: Reared from *Macrosiphum cucurbitæ* by the senior author at Lafayette, Ind.; reared from an aphidid on *Eragrostis* sp., by Mr. D. W. Coquillett; reared from *Macrosiphum* sp. on *Audibertia stochoides*, by Mr. Coquillett, at Los Angeles, Cal. Swept from *Eragrostis* sp. by the senior author at La Fayette, Ind., October 4, 1885; reared from *Myzus* sp. on *Hosackia glabra* by Mr. Coquillett at Los Angeles, Cal.; reared from *Myzus ribis* (currant aphis) by Prof. A. J. Cook, Lansing, Mich.; reared from *Aphis gossypii* by Prof. G. F. Atkinson, Columbia, S. C.; reared from *Macrosiphum* sp. on Abutilon by Mr. Coquillett at Los Angeles, Cal.; reared from *Aphis avenæ* by Mr. J. W. Barlow, June 20, 1882, at Cadet, Mo.; reared from Aphis on peach May, 1886, by Mr. Albert Koebele, Fresno County, Cal.; reared from an aphidid on *Baccharis viminalis* by Mr. Coquillett at Los Angeles, Cal.

There are probably many other hosts besides the ones we have mentioned of which as yet we have no knowledge; and when this situation is taken under consideration it is very easy to see that it would be only in rare instances and under peculiar conditions that a locality would be found where *Aphidius testaceipes* would not be lurking, waiting for favorable weather conditions and abundant supplies of its host aphidids to make its appearance in greater or less numbers.

HIBERNATION.

Aphidius is capable of withstanding extreme degrees of cold, as witnessed by the fact that Toxoptera parasitized during November, 1907, at Richmond, Ind., did not give up adults until the 27th and 28th of March and the 4th of April following. During February they were in the larval stage within an old dead body of a Toxoptera.

Mr. Kelly found that at Leavenworth, Kans., the parasites hibernated as larvæ and pupæ. This was shown by the fact that he found *Aphidius testaceipes* in the field in this condition on November 13, 1907. From a lot of 50 dead parasitized Toxoptera from the same field, that had been washed or rubbed off the leaves of the young grain and were taken out of the mud about the wheat plants on February 28, after the winter was practically over, Mr. Kelly found that 17 contained full-grown larvæ, 12 contained pupæ of a light color, and 21 contained pupæ of a dark color; the latter apparently were ready to develop promptly with the advent of warm weather. Mr. Kelly collected, on the same date and also from this same field, a number of Toxoptera in various stages of development that were hibernating in the fields and which showed no signs of parasitism; the weather had been such as to preclude the possibility of their having recently been parasitized. These were placed in a warm room and soon showed evidence of parasitism, *Aphidius testaceipes* being finally reared from them.

The junior author found that at Richmond, Ind., the adult Aphidius would live for at least two weeks when the temperature was below freezing. The parasites were taken into a warm room several times during these two weeks and they would become active, but when placed out of doors they would soon become numb. These adults were confined, however, so that excessive moisture was excluded, and they may not be able to live for so long a time in the fields unprotected.

The fact that Aphidius can during comparatively cold weather remain for a long period within the body of its host, and the latter give no external visible evidence of its presence, will readily account for the apparent absence of the parasite from any locality for an almost indefinite period; however, when the weather warms up sufficiently for development of the parasite to go on, its presence readily becomes apparent. For these reasons, as well as others that will be mentioned in their proper places, it is impossible to say, from a cursory examination, that Aphidius is not present.

INFLUENCE OF WINDS IN THE DISPERSION OF APHIDIUS TESTACEIPES.

As the natural suppression of an outbreak of Toxoptera is more dependent upon the activity of this parasite than of any other of its natural enemies, it is important to learn the extent to which the parasite is able to follow its host in its spread from the South over the country to the northward.

Dispersion of Aphidius may be accomplished in two ways—first, as larvæ in the bodies of the winged host insect, where it is usually invisible, and, second, by being carried bodily with the winds along with the host.

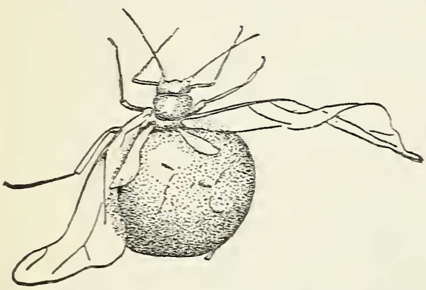


FIG. 29.—Winged female of the spring grain-aphis, parasitized by *Aphidius testaceipes*. Enlarged. (From Webster.)

By referring to Table XII on page 108, it will be observed that a number of cases are there recorded where individuals of *Toxoptera graminum* which were parasitized developed to winged adults, lived for a period of eight or nine days, and during this time gave birth to young, but from their dead bodies Aphidius afterwards issued. The presence of winged parasitized females on the leaves of grain and grasses inhabited by Toxoptera is of common occurrence (see fig. 29). Thus, while it has not been possible to observe the parasitism of individuals and follow out the final dispersion of the same, the evidence tending to show the probability of its general occurrence is so overwhelming that such direct proof does not seem necessary. With the obscurity

relative to this matter cleared away, it will be observed that it is entirely possible for great numbers of the adults, or those that are nearly mature, to become parasitized in a southern locality, the latter to develop to winged females under a more or less high temperature, and for both to be carried many miles to the northward, and then settle down and begin to reproduce, the Aphidius becoming adult and issuing later from the dead body of its host. In the meantime the offspring of the host Toxoptera would, of course, develop and themselves reproduce, some of them, without doubt, falling victims to the very parasite brought along by their parent. While this may not be the chief factor in the dispersion of this parasite, it probably enables it to follow along with the host insect and become diffused with it, although if low temperatures prevail after the time the migrating female settles in her new home there may be considerable delay in the issuing of the adult parasite without to any great extent delaying the development and preventing the increase of Toxoptera.

With the temperature at a point which enables Aphidius to become active there is no doubt that the parasite follows with the host insect, and, indeed, these parasites are usually found on the wing in the company of their hosts during warm sunny days. With high cold winds, which usually come from the northward and would tend to drive the parasites back over territory to which Toxoptera has already come and from which it has now largely disappeared, the adult Aphidius is observed to nestle down among the infested plants and not to venture abroad. Thus it is that this parasite is doubtless usually present in some form in the grain fields with the Toxoptera, though critical examinations of such fields may fail to reveal them until the temperature reaches a point that enables them to become active.

All of this is applicable to the insect in southern territory where no egg stage is yet known to occur. Aphidius occurs all over the country, and we have learned that in the North it winters as fully developed larvæ and pupæ within the "cocooned" bodies of its hosts, its emergence and activity in spring being controlled by the temperature and its dispersion influenced by the same forces and in much the same manner as in the South.

TEMPERATURE INFLUENCES ON APHIDIUS.

Probably the whole secret of these disastrous outbreaks of Toxoptera lies in the fact that this parasite is not active in a temperature much below 56° F., while, as has already been shown, the aphis begins to reproduce in a temperature at or slightly below 40° F.—a probable difference of at least 16° F. Therefore the situation in a field of wheat in the South in early spring may be described in this way: There are present many Toxoptera of all ages, with viviparous

reproduction continually going on during mild weather. Aphidius may also be present either as invisible undeveloped overwintering larvæ within the living bodies of its host, or it may be present as mature larvæ or pupæ in the dead and dried "cocooned" bodies of the same. Besides this, in the light of recent studies of Aphidius by Mr. Viereck, the same may be true with reference to its occurrence in a considerable number of other common species of aphidids, inhabiting a great variety of vegetation, in the same neighborhood, upon which this same species of Aphidius is parasitic. Thus, it is perfectly clear why, with Toxoptera swarming in the fields, and the parasite present, about 10 days, with the temperature ranging from 40° or 50° to 60° or 70° F., is sufficient to enable the latter summarily to suppress the invasion. The abruptness with which this change is brought about is easily explained by the fact that a parasitized female Toxoptera produces young during only a comparatively few days after being parasitized, although she may survive several days longer, especially if the weather be cool enough to retard the development of the parasite.

In the North the situation is usually quite different, as parasites can not begin their work here to any extent until after the eggs have hatched, and the stem mothers and their offspring have appeared in the fields, thereby furnishing host insects. The overwintering of immature Aphidius larvæ in the bodies of the host is in the North ordinarily precluded by the absence of living host individuals during severe winters, although mature larvæ may winter in the dead bodies of the host as in the South. Stem mothers are probably never present in great numbers and considerable time is therefore necessarily required for their offspring to become excessively abundant. For this reason parasitism, over the section where the host insects pass the winter in the egg, begins later, and, at the start, proceeds necessarily much slower than in the South, but on the other hand Aphidius, unless the winter be an exceptional one, must of necessity winter over in the "cocooned" bodies of its numerous hosts, as mature larvæ or pupæ, and would therefore promptly respond to the warm days of early spring, although delayed somewhat by low temperatures that might not retard the host insects.

There is one point in connection with parasitism by Aphidius that must be always kept in view, particularly to the southward, in order that mistakes and misstatements may be avoided regarding its actual occurrence in any particular locality. While the larva is contained within the still living body of its host its presence there is not easily detected. Indeed it is not until the larva becomes nearly full grown that it can be detected even by an expert. Therefore, in the light of what has previously been stated concerning the situation in milder latitudes, there may be millions of living larvæ

present for weeks in a field with no visible indication of their presence. Yet only a few warm days are required to bring about their final development, whereupon the presence of the more or less globular, leathery, brown bodies of the parasitized host first begin to attract attention and thus actually reveal the presence of the Aphidius, which has already been established there.

An excellent illustration of this is afforded by an occurrence of Toxoptera in eastern North Carolina, observed by Mr. L. M. Smith. In a small field of oats near Newport, wingless viviparous female Toxoptera and young were found in destructive abundance with no indication whatever of the presence of Aphidius. Yet when specimens of the pest submitted by Mr. Smith reached Washington, some of them were beginning to change color from the presence of Aphidius larvæ within their abdomens. Again, when Mr. C. N. Ainslie visited Wellington, Kans., April 1, 1907, he observed no trace of the presence of Aphidius, but upon returning to this same locality on April 10 he found them present. Only a few of the Toxoptera had yet become dark brown, but a large number showed the orange color that told the story of their parasitism. Therefore all statements made in previous publications relative to the lack of parasites, or to the extent to which they occurred in any field or locality, must be understood as applying only to either the adults or to the browned cocooned bodies of the host insects, and are not in any sense to be considered as indicating the extent to which these host insects were carrying obscured Aphidius larvæ about with them in their bodies to develop adults whenever there were a few sufficiently warm days.

EFFECTS OF WET WEATHER ON THE DIFFUSION OF APHIDIUS.

There is another element affecting the diffusion of this most efficient of natural enemies of Toxoptera, namely, protracted rains. When it is raining the parasite simply will not take wing at all or move about in a way to be affected by winds. This element will not admit of tabulation for the reason that a thunder shower followed by warm, bright sunshine tends to make these, as well as all winged insects, more active after the storm has passed. Thus, the amount of precipitation really means little, while a slow, drizzling, protracted rain (though the total precipitation may be much less) will keep the parasite in seclusion much more effectively. Hence it is that not only a comparatively high temperature accompanied by winds is essential, but the weather must also be fair and sunny.

In British East Africa Toxoptera is worse during seasons when there is much wet weather, and in the Orange Free State outbreaks of the pest seem to be also associated with similar meteorological conditions during spring.

Other Species of Aphidius.

Aphidius confusus Ashm. has been reared from Toxoptera from different parts of the country, including the Department of Agriculture grounds in Washington, but to what extent it assisted in overcoming Toxoptera in 1907 is not altogether clear. Its life history is apparently similar to that of *A. testaceipes* Cress., and its effect upon the aphides is apparently the same.

Aphidius avenaphis Fitch was reared from *Toxoptera graminum* in the insectary at the Department of Agriculture in Washington, the host insect having been parasitized, under observation, by adult virgin Aphidius reared from *Aphis* sp.

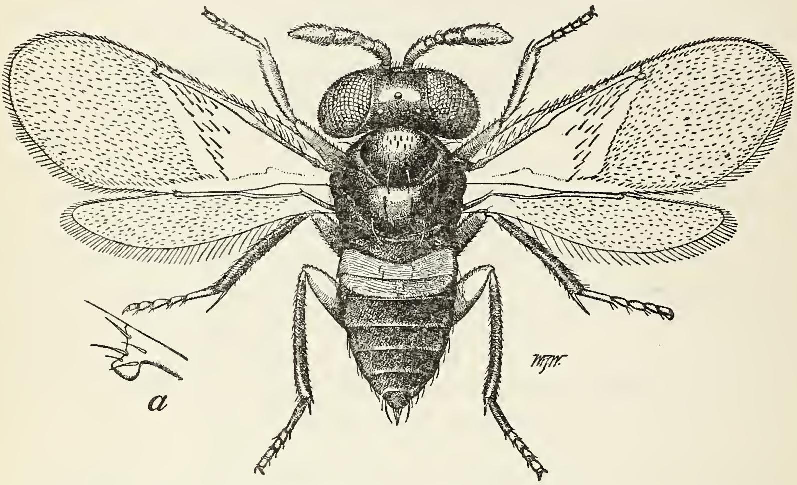


FIG. 30.—*Aphelinus mali*, a parasite of the spring grain-aphis. Greatly enlarged. *a*, Stigmal club, much more enlarged. (Original.)

Species of Aphidius, apparently undescribed, were sent to the bureau from Njoro, British East Africa, and the Orange Free State, South Africa, as enemies of *Toxoptera graminum* in that country.

Aphelinus.

We have reared three species of Aphelinus from *Toxoptera graminum; Aphelinus mali* Hald., *A. nigritus* How., and *A. semiflavus* How.

Aphelinus mali Hald. (fig. 30) was reared from Toxoptera at Lafayette, Ind., in 1885 by the senior author, by Mr. R. A. Vickery at Richmond, Ind., and from the same species at Clemson, S. C., by Mr. G. G. Ainslie. Messrs. Kelly, Urbahns, and Parks reared it from *Aphis setariæ* Thos. at Wellington, Kans. Messrs. Kelly and Urbahns also reared it from *Schizoneura americana* Riley at Wellington. Mr. Vickery reared it from *Schizoneura lanigera* Haussm. at Richmond,

Ind., and from *Colopha eragrostidis* Middl. at Mt. Vernon, Ind. Mr. Kelly reared it from *Pemphigus fraxinifolii* Riley and from an aphidid taken on *Panicum* sp. Mr. C. N. Ainslie reared it from *Macrosiphum rosæ* Linn., at Mesilla Park, N. Mex.

This species has been previously reared, as stated by Dr. L. O. Howard [1] from *Schizoneura lanigera* Haussm., *Colopha eragrostidis* Middl., *Aphis brassicæ* Linn., *Pemphigus fraxinifolii* Riley, *Aphis monardæ* Oestl., *Macrosiphum rosæ* Linn., *Aphis sacchari* Zehntn., and *Tetraneura colophoidea.*

Aphelinus nigritus How. (fig. 31) was first reared from Toxoptera at Spartanburg and Clemson, S. C., by Mr. G. G. Ainslie. It was

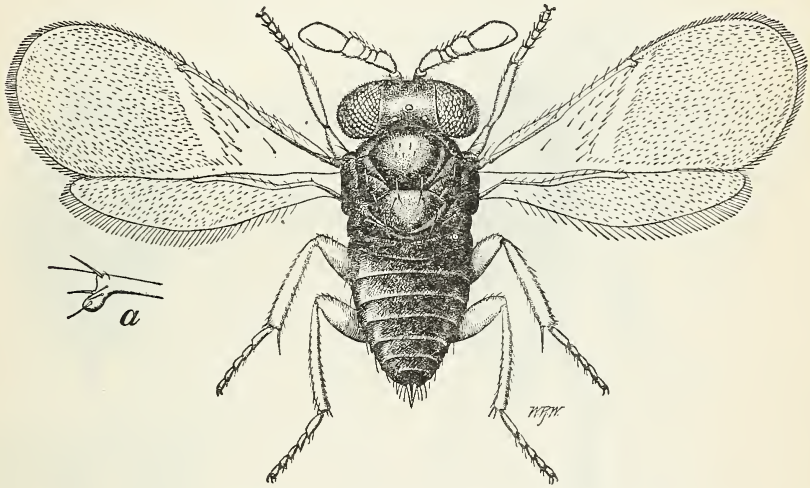


FIG. 31.—*Aphelinus nigritus*, a parasite of the spring grain-aphis. Greatly enlarged. *a*, Stigmal club, still more enlarged. (Original.)

reared from the same species of aphidid by Mr. C. N. Ainslie at Springer and Mesilla Park, N. Mex., and St. Anthony Park, Minn. Mr. T. H. Parks reared it from Toxoptera at Wellington, Kans., and Messrs. Kelly and Urbahns reared it from *Aphis setariæ* Thos. at Wellington.

Aphelinus semiflavus How. (fig. 32) was first reared from *Myzus persicæ* Sulz. and *Chaitophorus viminalis* Monell by Prof. C. P. Gillette at Fort Collins, Colo., in 1908. It was later reared by Mr. G. G. Ainslie from Toxoptera at St. Anthony Park, Minn., and from a black aphidid on bluegrass (probably *Rhopalosiphum poæ* Gill.) at Mesilla Park, N. Mex., by C. N. Ainslie.

[1] Ent. News., vol. 19, no. 8, pp. 365–366, 1908.

NOTES ON LIFE HISTORY AND HABITS OF APHELINUS.

Mr. C. N. Ainslie made some observations on *Aphelinus nigritus* at Mesilla Park, N. Mex., in 1908. He states that when the adult is ready to oviposit it approaches an aphidid very slowly and cautiously, moving or swaying its body slightly from side to side and waving its antennæ. When the antennæ finally touch the plant-louse it stops, turns suddenly about, moves backward slightly, and then gives the victim a thrust with its hairlike ovipositor. This operation apparently causes pain to the aphidid, as she begins to "kick up" her abdomen and there sometimes appears a tiny drop of fluid where the puncture was made.

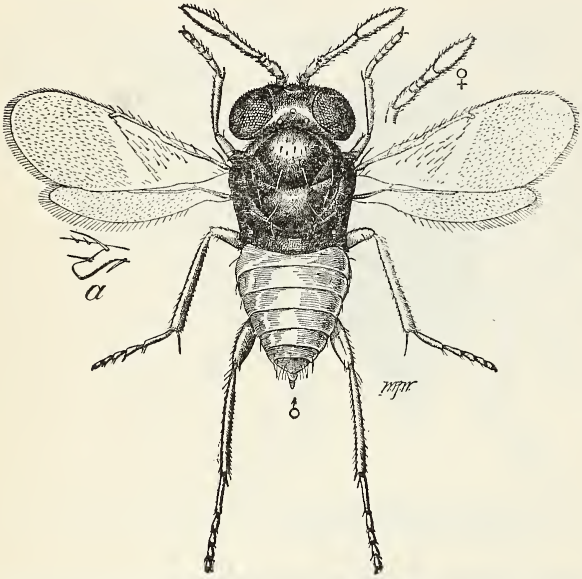


FIG. 32.—*Aphelinus semiflavus*, a parasite of the spring grain-aphis. Greatly enlarged. *a*, Stigmal club, still more enlarged. (Original.)

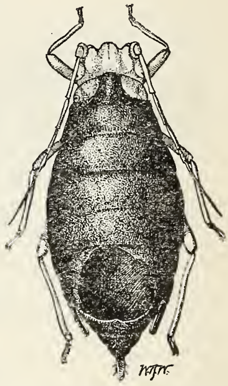


FIG. 33.—Dried remains of body of the spring grain-aphis from which adult *Aphelinus nigritus* has emerged. Enlarged. (Original.)

When the larva of *Aphelinus nigritus* is fully grown the body of the plant-louse, according to Mr. G. G. Ainslie, turns black and the legs a conspicuous white (fig. 33), while in individuals parasitized by *A. mali* these appendages are black. The body, however, of so small an aphidid as *Toxoptera graminum* appears to be but little swollen. Mr. C. N. Ainslie found that under favorable weather conditions *A. nigritus* developed from egg to adult in from 12 to 13 days.

The following diagram will serve to illustrate the different hosts of *Aphidius testaceipes*, *A. avenaphis*, *A. confusus*, *Aphelinus mali*, *A. nigritus*, and *A. semiflavus*, which we have shown to attack *Toxoptera graminum*. This will give some idea of the numerous sources from which an army of parasites may be recruited to oppose any serious invasion of Toxoptera.

Toxoptera graminum	*Aphidius*	*avenaphis*	*Macrosiphum granaria* Buck.
		confusus	*Macrosiphum erigeronensis* Thos.
		testaceipes	*Aphis avenæ* Fab.
			Aphis gossypii Glov. *Aphis* sp.
			Aphis maidis Fitch.
			Aphis maidi-radicis Forbes.
			Aphis medicaginis Koch.
			Aphis œnotheræ Oestl.
			Aphis rumicis Linn.
			Aphis setariæ Thos.
			Macrosiphum viticola Thos.
			Macrosiphum granaria Buckt.
			Melanoxantherium sp.
			Macrosiphum sp. on black gum.
			Myzus ribis Linn. on currant.
			Myzus sp. on *Hosackia glabra*.
			Macrosiphum sp. on Abutilon.
			Macrosiphum cucurbitæ Thos.
			Aphidid on *Ampelopsis* sp.
			Aphidid on *Baccharis viminalis*.
			Aphidid on *Capsella bursa-pastoris*.
			Aphidid on *Eragrostis* sp.
			Aphidid on *Kochia* sp.
			Aphidid on locust.
			Aphidid on peach.
			Aphidid on pigweed (?).
			Aphidid on plum.
	Aphelinus	*mali*	*Aphis brassicæ* Linn.
			Aphis monardæ Oestl.
			Aphis sacchari (?) Zehntn.
			Aphis setariæ Thos.
			Colopha eragrostidis Middl.
			Myzus mahaleb Boyer.
			Pemphigus fraxinifolii Riley.
			Macrosiphum rosæ Linn.
			Schizoneura americana Riley.
			Schizoneura lanigera Haussm.
			Tetraneura colophoidea (?).
		nigritus	*Aphis setariæ* Thos.
		semiflavus	*Aphis maidis* Fitch.
			Aphis gossypii (?) Glover.
			Chaitophorus viminalis Mon.
			Myzus persicæ Sulz.

SECONDARY PARASITES.

Megorismus sp.

Species of the genus Megorismus, it appears, have been previously considered as primary parasites. Mr. Parks, however, has conducted some experiments with a species (fig. 34) at Wellington, Kans., and his results clearly indicate that in this case it is a secondary parasite. In no instance could he rear it from aphidids

that had not previously been parasitized; he experienced no difficulty, however, in rearing it when the adults were placed in cages with aphidids that were brown, having been killed by some species of Aphidius. It may be that under certain conditions *Megorismus* sp. is also a primary parasite. Mr. Parks finds that it takes about 30 days in developing from egg to adult in a temperature of about 70° F. indoors.

It has been reared in conjunction with *Aphidius* sp. from *Toxoptera graminum* and *Chaitophorus* sp. at Wellington, Kans., by Messrs. Kelly and Urbahns; from *T. graminum* and *Aphis brassicæ* in the same locality by Mr. Parks. Mr. Parks also reared it from *Macrosi-*

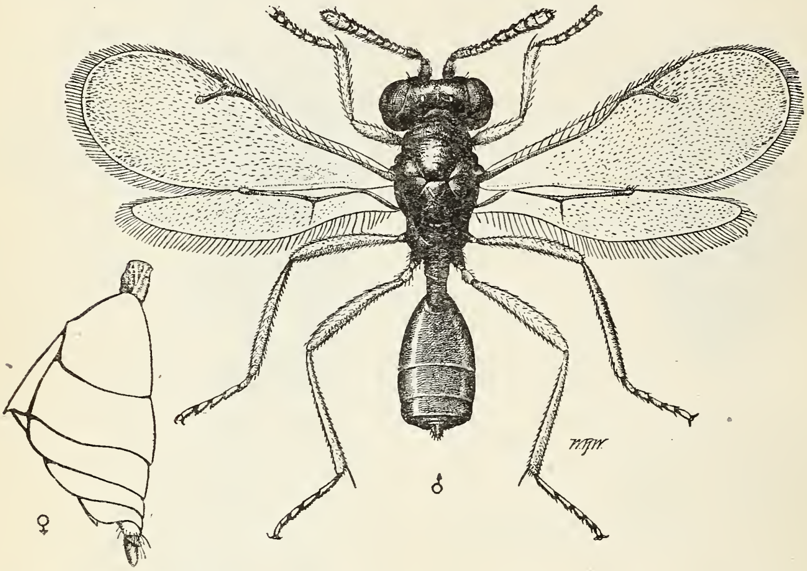


FIG. 34.—*Megorismus* sp., a secondary parasite of the spring grain-aphis: Male, greatly enlarged; female abdomen, more enlarged, at right. (Original.)

phum pisi at Washington, D. C. Mr. C. N. Ainslie reared it from *Hyalopterus dactylidis* in the same locality, and the junior author reared it from *Myzus persicæ* at Lafayette, Ind.

Aphidencyrtus aphidiphagus Ashm.

The species *Aphidencyrtus aphidiphagus* Ashm. (fig. 35) has also been considered a primary parasite, and while we have no direct evidence to disprove this we very strongly suspect that it is in this case a secondary parasite. Like Megorismus, which, we have shown, is sometimes, at least, a secondary parasite, we have reared it only in conjunction with known primary parasites. Mr. G. G. Ainslie could rear it only in connection with *Aphelinus* sp. from *T. graminum* at Clemson, S. C., and Mr. C. N. Ainslie reared it from *Aphis*

brassicæ at Mesilla Park, N. Mex., in conjunction with *Aphidius* sp. Nothing definite is known of its life history.

Pachyneuron sp.

A species of Pachyneuron (fig. 36) has been repeatedly reared from *Toxoptera graminum* and it appears to be generally accepted as a

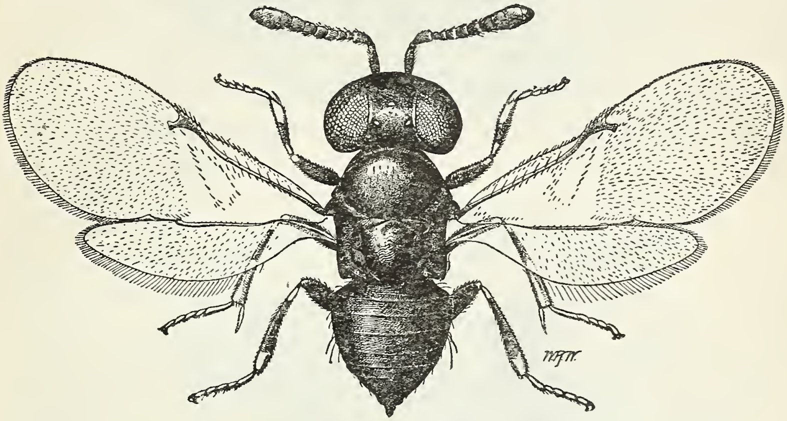


FIG. 35.—*Aphidencyrtus aphidiphagus*, a secondary parasite of the spring grain-aphis. Greatly enlarged. (Original.)

secondary parasite. Mr. Kelly has observed it ovipositing in brown parasitized *Macrosiphum viticola*. Mr. G. G. Ainslie reared it in conjunction with *Aphelinus* sp. from Toxoptera and with *Aphidius* sp. from

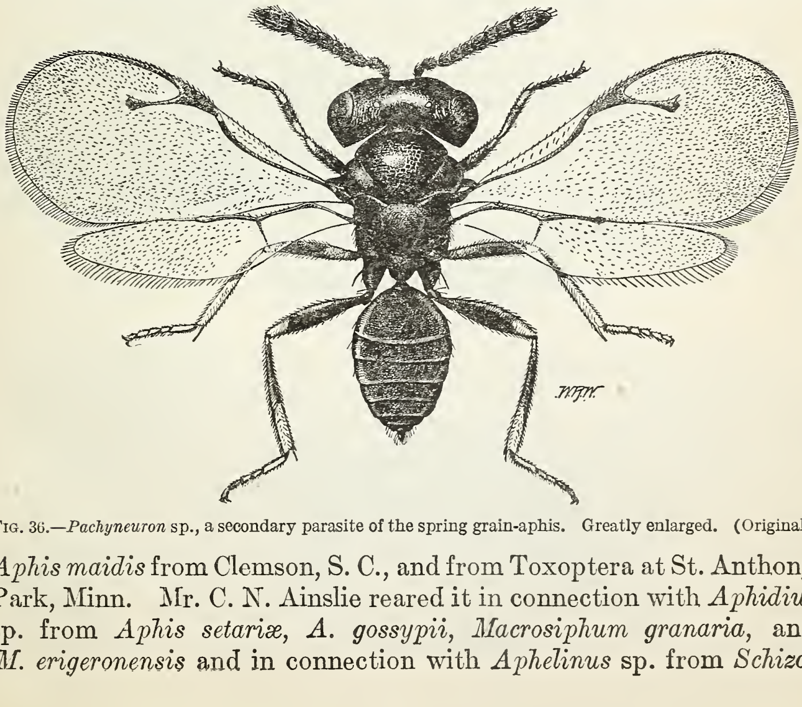


FIG. 36.—*Pachyneuron* sp., a secondary parasite of the spring grain-aphis. Greatly enlarged. (Original.)

Aphis maidis from Clemson, S. C., and from Toxoptera at St. Anthony Park, Minn. Mr. C. N. Ainslie reared it in connection with *Aphidius* sp. from *Aphis setariæ*, *A. gossypii*, *Macrosiphum granaria*, and *M. erigeronensis* and in connection with *Aphelinus* sp. from *Schizo-*

neura americana. He also reared it from *Macrosiphum viticola* and *Chaitophorus* sp. *Pachyneuron* sp. appears to be quite generally distributed but little or nothing is known of its life history.

Allotria sp.

Allotria sp. (fig. 37) is recorded as a secondary parasite. Mr. Parks verified this by careful rearings at Wellington, Kans., in 1909, for he was able to rear it only from parasitized aphidids. The junior author and Messrs. Kelly and Urbahns have observed it ovipositing in parasitized dead aphidids also. Mr. Parks found in his experiments that it developed from egg to adult in about 21 days, under favorable temperatures.

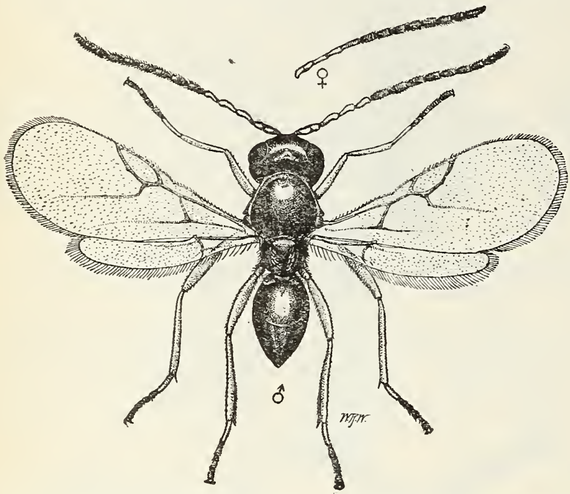


FIG. 37.—*Allotria* sp., a secondary parasite of the spring grain-aphis. Male, with female antenna at upper right. Greatly enlarged. (Original.)

We have reared it only in conjunction with Aphidius. Messrs. Kelly and Urbahns reared it from *Aphis gossypii* and *A. brassicæ* at Wellington, Kans.; Mr. Parks reared it from Toxoptera from the same locality; Messrs. Parks and Kelly also reared it from Toxoptera at Washington, D. C. Mr. C. N. Ainslie reared it from *Aphis avenæ* and *Hyalopterus dactylidis* from the same locality. Mr. Kelly reared it from *Macrosiphum viticola* from Wellington, Kans., and the junior author reared it from *Myzus persicæ* at Lafayette, Ind.

PREDACEOUS ENEMIES.

Lady-beetles.

Probably next in importance to the genus Aphidius come the ladybird beetles. These beetles, in both the adult and larval stages, feed upon plant-lice. In 1907 they became very abundant, destroying countless numbers of Toxoptera and greatly assisted Aphidius in subduing the pest. Plate VIII represents the manner in which the pupæ are found attached to plants in fields badly infested with Toxoptera; to the left is a 2-inch section of an old cowpea stem; to the right, two short sections of wheat stems. Oftentimes as many as 30 or more pupæ could be found within the space of a foot of a single drill row. Adults deposit eggs upon any convenient object,

Fig. 1.

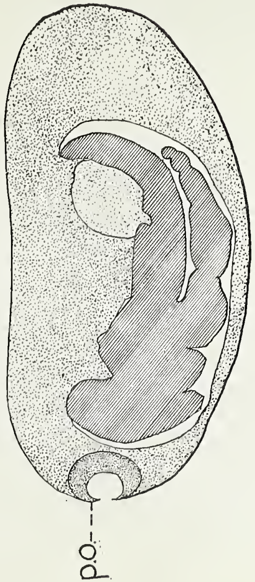


Fig. 2

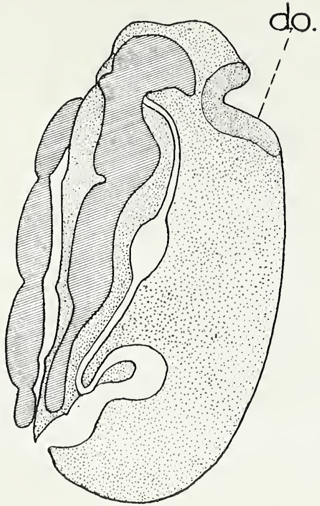


Fig. 3

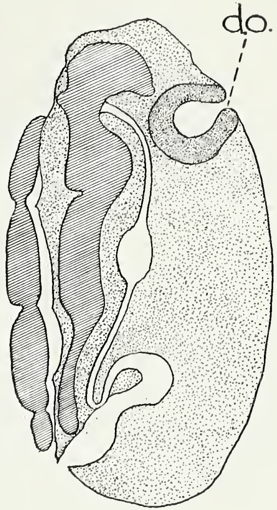
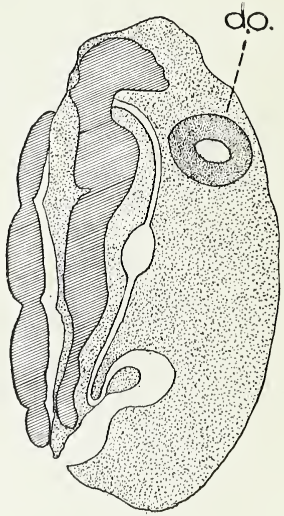


Fig. 4.



DEVELOPMENT OF THE EMBRYO IN THE EGG OF TOXOPTERA GRAMINUM.

Fig. 1.—Sagittal section (slightly oblique) showing the embryo in position to escape from the center of the egg. Magnified 83 diameters. Fig. 2.—Sagittal section (slighty oblique) showing the embryo at the surface of the egg. Dorsal organ now formed. Magnified 83 diameters. Fig. 3.—Sagittal section (slightly oblique), later stage of development. Magnified 83 diameters. Fig. 4.—Sagittal section (slightly oblique): The dorsal organ is immersed within the body cavity where it has begun to disintegrate. Magnified 83 diameters. (Original.)

A LADY-BEETLE ENEMY OF THE SPRING GRAIN-APHIS.

Pupæ of *Hippodamia convergens* attached to stem of cowpea and wheat straws in a field where the spring grain-aphis had been excessively abundant. Enlarged. (Original.)

and, as soon as hatched, the larvæ seem possessed of an insatiable appetite, devouring aphidids or even eggs and larvæ of their own species if no plant-lice are at hand. Mr. Kelly has found that an

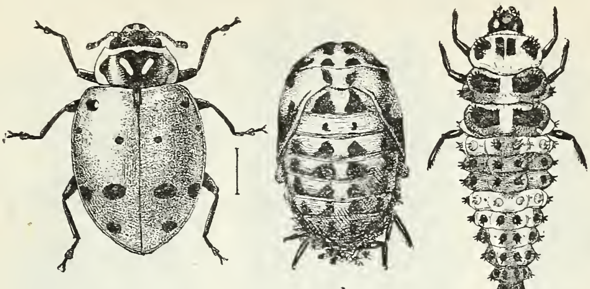


FIG. 38.—The convergent lady-beetle (*Hippodamia convergens*), an enemy of the spring grain-aphis: *a*, Adult; *b*, pupa; *c*, larva. Enlarged. (From Chittenden.)

adult ladybird (*Hippodamia convergens*) (fig. 38) will devour from 15 to 30 plant-lice in a day. Mr. S. J. Hunter, in "The Green Bug and its Enemies," page 6, states that instances have come under his observation where as many as 100 have been devoured in a single day by an adult lady-beetle. The larvæ when nearly grown are probably able even to exceed this record. In one of Mr. Kelly's experiments a single beetle deposited as many as 264 eggs, thus showing that this ladybird is very prolific. When all of these facts are considered it is easy to see that the lady-beetles are rather formidable enemies of Toxoptera.

FIG. 39.—The nine-spotted lady-beetle (*Coccinella 9-notata*), an enemy of the spring grain-aphis: Adult. Enlarged. (From Chittenden.)

Hippodamia convergens appeared to be by far the most abundant ladybird in the Southwest in 1907. *Coccinella 9-notata* (figs. 39, 40) and *Megilla maculata* (fig. 41) were also quite abundant. *Coccinella abdominalis* was present in less abundance. *Adalia flavomaculata* DeG. (fig. 42), with its larvæ, has been sent to the bureau as an enemy of Toxoptera in the Orange Free State, South Africa.

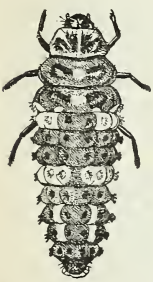


FIG. 40.—The nine-spotted lady-beetle (*Coccinella 9-notata*), an enemy of the spring grain-aphis: Larva. Enlarged. (From Chittenden.)

Syrphid Flies.

All through the Southwest in 1907 syrphids were very abundant and were an important factor in the control of Toxoptera.

These insects are beautiful two-winged flies with prominent golden bands across the abdomen. They are always present in mild weather

in grain fields badly infested with plant-lice, and when quite numerous attract attention by a buzzing noise made while in flight. The predaceous larvæ are sluglike and of a dirty grayish or yellowish green color; this is the only stage in which they are destructive to

FIG. 41.—The spotted lady-beetle (*Megilla maculata*), an enemy of the spring grain-aphis: *a*, Larva; *b*, empty pupa skin; *c*, adult. Enlarged. (From Chittenden.)

plant-lice. Little is known of the life histories of these insects as very few careful rearings have been made.

Syrphus americanus Wied. (fig. 43) and *Eupeodes volucris* O. S. (fig. 44) were by far the most numerous syrphids in the grain fields in the Southwest in 1907. A field at Kingfisher, Okla., in April, 1907, literally swarmed with them; 20 or more could be taken with each sweep of an insect net. A curious fact with reference to their occurrence in such abundance in this field, however, was that Toxoptera was not present there in destructive abundance, while the adjoining field was suffering greatly from their attack, though, curiously enough, the syrphid flies did not appear to be so plentiful there. These two species were present, apparently, over the entire southwestern area that suffered greatly from Toxoptera attack in 1907. *Syrphus americanus* was reared also from Toxoptera material sent in by Mr. E. C. Haynsworth from Sumter, S. C. Prof. J. M. Aldrich states in his catalogue of North American Diptera that he reared *Eupeodes volucris* from *Aphis avenæ* at Moscow, Idaho. Dr. C. V. Riley states,

FIG. 42.—A South African lady-beetle, *Adalia flavomaculata*, which with its larva attacks the spring grain-aphis in the Orange Free State, South Africa. Enlarged. (Original.)

in a report of the Department of Agriculture,[1] that he reared *Syrphus americanus* from *Macrosiphum granaria.*

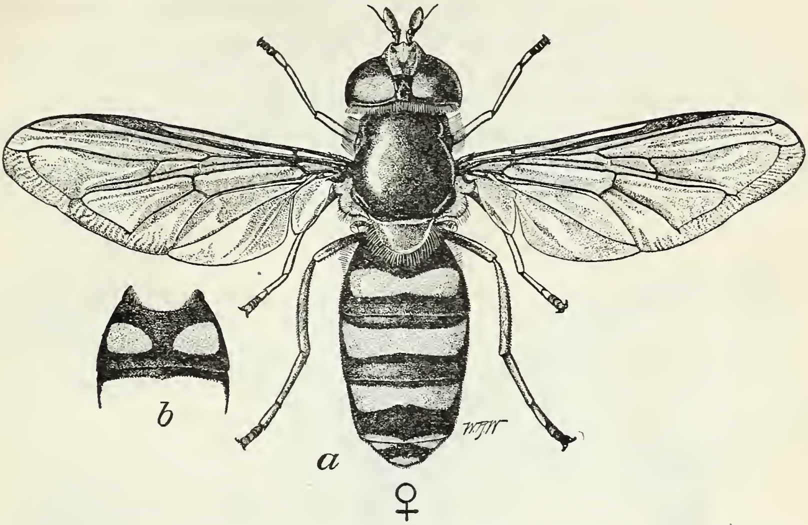


FIG. 43.—*Syrphus americanus,* whose larva destroys the spring grain-aphis: *a,* Female fly; *b,* second abdominal segment of male. Enlarged. (Original.)

Sphærophoria cylindrica Say (fig. 45) was collected from wheat fields at Hiawatha, Kans., in 1907, by the junior author and was also

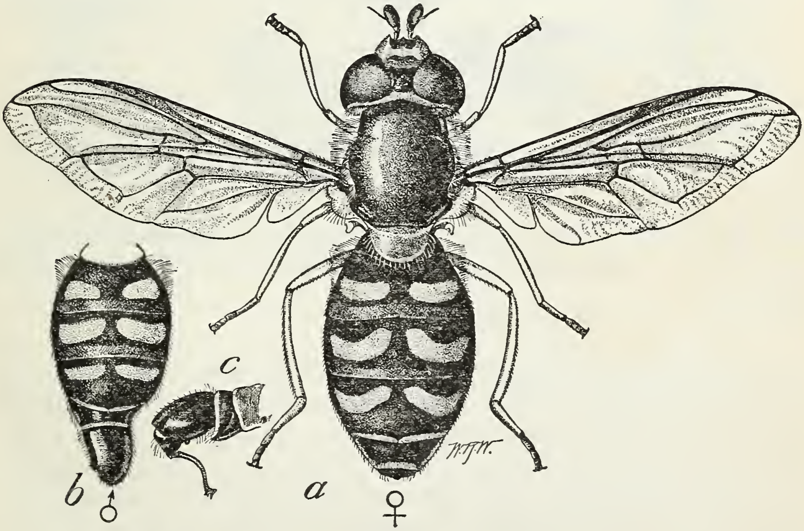


FIG. 44.—*Eupeodes volucris,* whose larvæ were the most abundant and useful in the fields where the spring grain-aphis was most abundant in the Southwest during the spring of 1907. *a,* Female fly; *b,* abdomen of male; *c,* hypopygium of male. Enlarged. (Original.)

reared from Toxoptera material sent in by Mr. Haynsworth from Sumter, S. C., the same year. Mr. G. G. Ainslie reared it from

[1] Report of the Entomologist, U. S. Dept. of Agr. for 1889, p. 351.

Toxoptera at Monetta, S. C., in 1908. Dr. Riley states that he found the larvæ feeding on *Macrosiphum granaria.*

Mr. Ainslie took quite a number of *Allograpta obliqua* Say in the Southwest in 1907, and, though we can not say definitely that it feeds upon Toxoptera, the chances are that it does, as Dr. Riley states that it feeds upon *Macrosiphum granaria.*

Mr. Kelly reared a number of *Baccha clavata* Fab. from *Aphis setariæ* at Wellington, Kans., in 1908; Mr. R. A. Vickery also reared *B. clavata* from *Aphis maidis* at Brownsville, Tex., in 1911; Mr. J. J. Davis reared this species at Lafayette, Ind., from *Aphis medicaginis,* also in 1911. This species may in future be found to attack Toxoptera also.

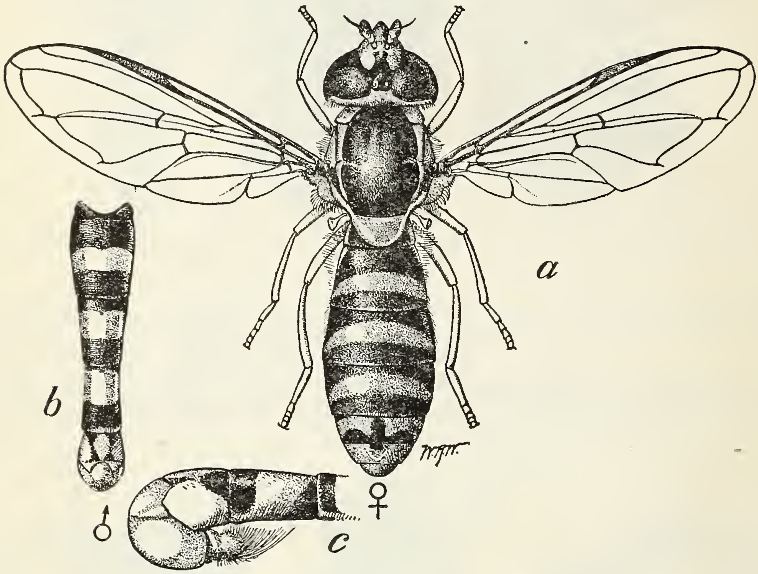


FIG. 45.—*Sphærophoria cylindrica,* a fly reared from larvæ attacking the spring grain-aphis in South Carolina in 1907: *a,* Female fly; *b,* dorsal view of abdomen of male; *c,* hypopygium of male, lateral view. Enlarged. (Original.)

Lace-Wing Flies.

The lacewing fly *Chrysopa plorabunda* Fitch was quite abundant in the grain fields in the Southwest in 1907 and without doubt assisted materially in the destruction of Toxoptera. This is the most common species in this section of the country, where it hibernates in the adult stage; thus, whenever the weather becomes suitable it is ready to at once begin oviposition. An allied species is shown in figure 46.

The larvæ of these insects can move about quite freely and are provided with two long, curved mandibles (see fig. 46) upon which

plant-lice or other insects are impaled and held prisoners until they are sucked dry. They are then released and the Chrysopa larvæ hunt other victims.

Cecidomyiidæ.

During September of 1909, at Lafayette, Ind., a new predaceous insect enemy to Toxoptera was discovered in the larvæ of a little cecidomyiid or two-winged fly, determined tentatively for us as *Aphidoletes* sp. by Dr. E. P. Felt. It was first observed in one of the stock cages and afterwards it was found to be reproducing in the fields on *Myzus persicæ.*

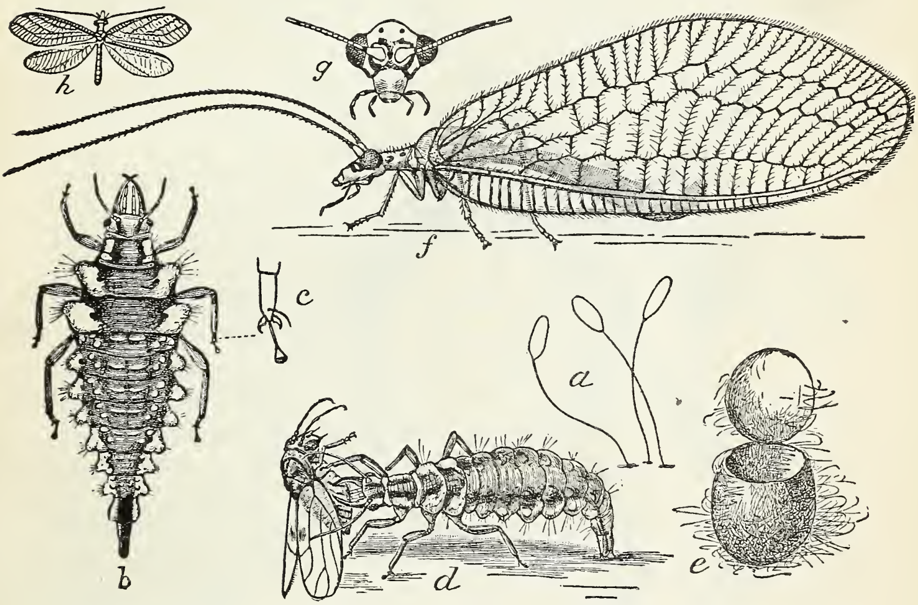


FIG. 46.—The golden-eyed lace-wing fly (*Chrysopa oculata*), an enemy of the spring grain-aphis. *a*, Eggs; *b*, full-grown larva; *c*, foot of same; *d*, larva devouring an insect; *e*, cocoon; *f*, adult insect; *g*, head of same; *h*, adult, natural size. All enlarged except *h*. (From Marlatt.)

We have not as yet carefully studied the life history of *Aphidoletes* sp. The adult fly (fig. 47) is a frail little creature, about the size of the clover-seed midge, pale cream in color, and the abdomen has a pinkish tinge, due to the pink eggs within. The eggs resemble those of the Hessian fly very closely except that they are much smaller. The larvæ (fig. 48), which are pinkish in color, descend to the ground when fully matured, and at or near the surface they spin a loose cocoon, to which particles of dirt and trash adhere. In a few days the adults issue. The time required for this little insect to complete the entire life cycle is apparently about 10 to 14 days. The species is not determinable further than the genus for the reason that only the female adults have been secured.

This little fellow goes about getting its meals in a very quiet, unobtrusive sort of way. It crawls quietly up among a number of Toxoptera and the first one it touches becomes its victim. It attaches its mouthparts to some joint of the legs, usually at the articulation of the femur and tibia, and sucks out the juices of the aphidid. With a compound miscroscope the blood can readily be seen flowing in a constant stream, through the limb of the aphidid attacked, into the larva of the cecidomyiid. Rarely is the aphid disturbed and upon close observation the skin of the aphidid will be seen to

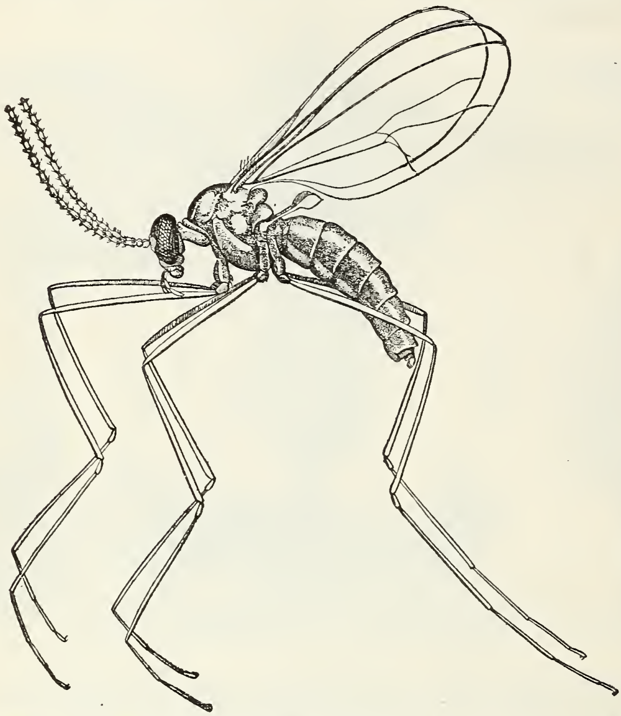


FIG. 47.—*Aphidoletes* sp., cecidomyiid fly whose larvæ feed upon the spring grain-aphis. Greatly enlarged. (Original.)

gradually shrivel up; finally nothing but the empty skin remains and the larva crawls away in search of more aphidids, frequently with the old empty aphidid skin adhering to it. The time required to consume the juices of an aphidid varies with the size of the larva and of the aphidid. A larva that is about full grown can dispatch a small aphidid in a few minutes, while from 15 to 30 minutes are required for it to empty a full-grown one. These cecidomyiid larvæ have enormous appetites and apparently keep up their work of destruction almost constantly until they become full grown.

It is not at all impossible for this insect to become a very important factor in the control of Toxoptera, as the adults are capable of flight and deposit large numbers of eggs.

Birds.

Birds devour immense numbers of the spring grain-aphis. Miss Margaret Morse, of Clark University, has been kind enough to conduct some experiments for us in feeding Toxoptera to quail. She has learned that they are very fond of the aphidids and estimates that about 5,000 individual Toxoptera were eaten by a single quail in one day, preference being shown for those that were unparasitized.

Mr. W. L. McAtee, of the Biological Survey of the United States Department of Agriculture, made some special studies of the aphis-eating habits of some of our birds in March-April, 1909, at Winston-Salem, N. C., at the time Toxoptera was so destructive in that vicinity. He states that in a wheat field of about 100 acres there were over 3,000 birds present daily; sometimes the number ran as high as 8,000 to 9,000. So large a number of birds would be found in the fields only during migration, and even at that time the presence of so many indicates that they were attracted to the fields by the abundant food. In so far as could be ascertained, about nine-tenths of the birds were feeding upon aphidids (including *Toxoptera graminum*, *Macrosiphum granaria*, and *Aphis avenæ*), some taking as many as 180 at a single meal. These aphidids are very small, soft-bodied insects and many meals would be required by a bird in a single day to satisfy its hunger. The average number per meal was at least 50, and we may assume that 6 times this number were taken per day. On this basis the number of aphidids destroyed by birds on the farm daily during the migration season is 90,000. Below is a partial list of the species Mr. McAtee found devouring Toxoptera at Winston-Salem. A complete list can not be given at this time, since his studies are not yet finished; many species will undoubtedly be added.

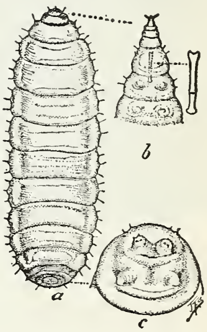


FIG. 48.—*Aphidoletes* sp., cecidomyiid larva which attacks the spring grain-aphis. *a*, Larva; *b*, anterior extremity protruded, showing breastbone; *c*, ventral view of posterior segment. *a*, Much enlarged; *b*, *c*, greatly enlarged. (Original.)

Goldfinch (*Astragalinus tristis*).
Vesper sparrow (*Poœcetes gramineus*).
Savanna sparrow (*Passerculus sandwichensis savanna*).
Chipping sparrow (*Spizella socialis*).
Song sparrow (*Melospiza melodia*).

All of these birds occur over the entire South.

MISCELLANEOUS ENEMIES OF TOXOPTERA.

Under the head of miscellaneous enemies may be considered enemies that are of very slight economic importance; those, in other words, that have been observed occasionally attacking Toxoptera.

In 1890 the senior author, at Lafayette, Ind., found that the young of the snowy tree-cricket (*Œcanthus niveus* De G.) were very fond of Toxoptera and fed upon them freely.

Mr. A. N. Caudell, of this bureau, observed one of the soldier bugs, *Reduviolus ferus* L., attacking Toxoptera on the grounds of the Department of Agriculture at Washington in 1908. During the same year Mr. C. N. Ainslie found a larva of a species of the ladybird genus Scymnus at Mesilla Park, N. Mex., attacking Toxoptera, and he seems to think that numbers are devoured by this insect.

In 1909, at Washington, D. C., Mr. R. A. Vickery reared the braconid *Lipolexis piceus* Cress. in limited numbers from Toxoptera.

The junior author has at times found a fungous disease attacking the aphidids in his rearing cages, but we have never noted this in the fields.

ANTS AND THEIR RELATION TO TOXOPTERA.

So far as our observations go Toxoptera is not so attractive to ants as are many other species of plant-lice. We have often found various species of ants in attendance on Toxoptera, but the relations did not appear to be mutually beneficial, the ants nearly always gaining the most by such partnerships.

At Hooker, Okla., in 1907, the junior author found ant burrows beside plants in an area badly infested with Toxoptera. In this case some burrows were found where the aphidids were slightly below ground on plants in these burrows, the ants being busy about the aphidids, stroking them with their antennæ. Mr. C. N. Ainslie many times observed ants stroking Toxoptera with their antennæ. We have found no instances, however, in which ants care for the eggs of Toxoptera in winter, and Toxoptera does not appear to excrete so much honeydew as do some other aphidids. This probably accounts for the fact that they are not so popular with the ants as are certain other aphidids.

In Texas, during 1909, Mr. T. D. Urbahns found ants busily caring for Toxoptera in his rearing cages. He also noted that the ants always attacked the parasite of Toxoptera (*Aphidius* sp.) whenever they came in contact with it, tearing the larvæ out of the old dead bodies of Toxoptera and destroying them.

REMEDIAL AND PREVENTIVE MEASURES.

With an outbreak of this pest fully established, and the winged adults being carried by the winds and scattered over the fields, there to settle down and reproduce, the difficulties in the way of control are quite insurmountable.

FIELD EXPERIMENTS.

The brush-drag experiments that were carried out under the direction of the junior author at Hobart, Okla. (see Plate IX, fig. 1), have not, with the trials we have given the brush drag, proved satisfactory, although Mr. Thos. J. Anderson, Government entomologist of British

FIG. 1.—BRUSH DRAG USED BY THE JUNIOR AUTHOR IN EXPERIMENTS AND ALSO BY FARMERS IN DESTROYING THE SPRING GRAIN-APHIS IN THE FIELDS AT HOBART, OKLA. (ORIGINAL.)

FIG. 2.—ROLLER USED IN EXPERIMENTS BY JUNIOR AUTHOR AND BY FARMERS IN DESTROYING THE SPRING GRAIN-APHIS IN OKLAHOMA. (ORIGINAL.)

East Africa, states that it is with them the most effective measure at their command for destroying the "green fly" in wheat fields. With us it was used after the aphidid had fully established itself and was literally swarming over the growing grain. Earlier, at the commencement of an outbreak, the effect of its use might prove more satisfactory.

Similar experiments were carried out with a heavy roller, such as is generally used among farmers for crushing clods in fields and compacting the ground. (See Pl. IX, fig. 2). In this case the results were even less satisfactory than with the brush drag, because the roller acted only on the clods and other inequalities in the surface of the ground. Where the wheat had been drilled the effect on the Toxoptera was less decisive than where the grain had been sown broadcast. The wheat plants grow in the narrow furrows or grooves and the insects that were displaced dropped down about the plants and the passing roller struck only the ridges, leaving the insects practically untouched.

Where the invasion is not chiefly from outside the field itself, and the pest makes its first appearance in spots, management is less difficult. By plowing under these infested spots and immediately harrowing and rolling them further damage may be effectually prevented. The junior author had an opportunity to test this measure in western Oklahoma. Covering these spots with straw, where easily obtainable, and burning, is equally effective, but where this last measure was applied by farmers in Oklahoma in 1907 the fields were so completely overrun from the outside that the good effects were entirely obliterated.

As between these two methods of suppression, it must be borne in mind that while the seriously affected spots in a field are very small, a single load of straw will suffice to cover a number of them, preparatory to burning, but after these areas become enlarged it is much more practicable to plow them under.

Besides the above-mentioned methods of control, experiments were conducted with different kinds of spray materials. In all of our control methods we endeavored to place ourselves in the position of the farmer, and to use such apparatus as could be obtained locally. Accordingly the junior author, upon reaching Hobart, Okla., the first week in April, 1907, prepared to begin some spraying experiments. The only spray apparatus that could be found in the town was a knapsack pump. As stated above, since an outbreak of Toxoptera starts in small areas, where the infestation originates within the field, it was thought possible to accomplish something by spraying these areas. As the infestation at Hobart seemed to be quite general, apparently originating from migrations from farther south and east, the small pump was found to be utterly useless. From here the junior author proceeded to Kingfisher, Okla., where there were clearly defined areas of infestation, and, together with

Mr. C. N. Ainslie, began experiments with a barrel pump, loaned by a market gardener. One plat was sprayed with 5 per cent kerosene emulsion; another with 10 per cent kerosene emulsion; a third plat with ordinary hard soap, 1 pound to 4 gallons of water; a fourth plat with whale-oil soap, 1 pound to 6 gallons of water. The spraying was done carefully, so as to reach every aphis possible. Upon examination the next day it was found that the 10 per cent emulsion and the hard soap had injured the plants. Not more than 50 per cent of the plant-lice were killed in any of the experiments. On the 15th of April the sprayings were repeated with similar results. All of the aphidids could not be reached, no matter how thoroughly the spraying was done. It was quite evident that unless the ground was almost soaked there would be little or no relief. These sprayings cost at the rate of about $4 per acre.

During the latter part of July it was found that Toxoptera was very abundant on the lawns of the Department of Agriculture at Washington, D. C. This outbreak became known to Mr. E. M. Byrnes, Superintendent of Experimental Gardens and Grounds, who at once had the entire infested block sprayed with a solution of one-half gill of blackleaf tobacco extract to each gallon of weak soapsuds. The application was, however, ineffective. Four days later a strip through this plat was thoroughly saturated with a strong solution of barnyard manure, made by soaking the manure in water. While there was no evidence that this killed any of the "green bugs," after nine days the pest was visibly less on this area than where the application of manure solution was not made.

A series of experiments was then undertaken under the senior author's direction by Mr. E. O. G. Kelly, as follows:

Tobacco dust was applied at rates of one-fourth, one-half, and 1 pound to each 100 square feet, but after over a week had elapsed from the date of application no effect was to be observed and no dead insects were found.

Kerosene emulsion was applied at 8 and 10 per cent strengths, and at the end of nine days no "green bugs" were to be found on the areas so treated. Also there was no perceivable injury to the grass.

Whale-oil soap solutions, varying in strength from one-fourth of a pound to 2 pounds of soap to each 5 gallons of water, were applied to similar areas. In this case the stronger solution injured the grass slightly, but not permanently; in the case of the lesser strengths there was no injury to the grass whatever. The effect on the "green bug" was the same in every case. They were not only literally exterminated over the areas treated, but the applications seemed to protect from a reinfestation, in case of even the weakest solution. An examination five days after the application was made revealed the "green bugs" in myriads and breeding freely on the untreated space, while only 8 inches away and on the treated area living bugs were

scarcely to be found, although the dead bugs were to be observed almost as abundantly as were the living on the space untreated. It must be remembered, however, that these experiments were carried out in grass kept closely cropped by frequent use of the lawn mower, and such areas can be sprayed much more effectively than a wheat field, where the ground would have to be literally soaked in order to reach all of the aphidids.

In the light of these experiments field spraying seems an impractical measure, even when small areas are involved. Burning or plowing would probably be more effective and the recommendations would probably be more readily complied with, as the average farmer does not usually have spray pumps of any description.

Lime and sulphur was dusted on the plants in badly infested areas with practically no benefits.

CULTURAL METHODS.

Examination of a large number of fields infested by Toxoptera, extending over a wide range of country, resulted in securing a considerable mass of information that may be included under the head of cultural methods.

The senior author visited Sumter, S. C., April 17, 1907, driving over much of the country in that vicinity. All fields of fall-sown oats, the only grain grown, were infested, there being no perceivable difference in severity of attack between fields following cotton, those following oats, and those on new ground, thus showing that the pest had swept over the country, diffusing itself generally.

At Winston-Salem, N. C., April 19–20, where both wheat and fall oats were grown, the ravages of the pest were much more serious, and fall-sown oats were completely ruined. A part of one field that had been in oats the previous year had, that fall, thrown up a heavy growth of volunteer grain, while the remaining portion was free of this growth. Wheat was drilled directly across both these areas on November 15, 1906, the whole field having first been prepared by disking, leaving much of this volunteer grain undisturbed. April 20, 1907, when examined by the senior author, the wheat on the part that had been overgrown with volunteer oats the previous fall was totally ruined, while on the clean part the damage was about 50 per cent. In wheat fields generally there was a marked difference in severity of attack as between those seeded before and those sown after about November 1, 1906, the later-sown suffering little while that sown earlier, on ground where there was much volunteer wheat or oats, was seriously damaged. This indicated that the trouble had been aggravated by the volunteer growth at the time of wheat seeding the previous autumn. It was very significant that in late-sown fields on clean ground the injury was comparatively small.

In Oklahoma it was observed by both the junior author and Mr. C. N. Ainslie that late-sown and pastured fields were destroyed much

more quickly and completely than earlier sown, unpastured fields. But it must be remembered that here the almost universal destruction was caused principally by Toxoptera drifting in from outside sources.

One feature of attack by Toxoptera has been especially noticeable throughout most portions of the country seriously ravaged by the pest, particularly where only wingless viviparous females have been found. In such fields the destruction was confined to circular areas which constantly increased in size as the season advanced, so long as meteorological conditions favorable to the increase of the pest prevailed; unless, in the meantime, the entire field had become overrun from the swarms drifting in from without. The occurrence of these spots (see Plate I, fig. 2) in the fields, while general, is not universal. For instance, the senior author did not observe them in the fields of fall-sown oats in South Carolina, in April, 1907, but he did find them about Winston-Salem, N. C., a day or two later. At Summers, Ark., Mr. C. N. Ainslie, observed a field of wheat, March 18, 1907, where a rectangular strip at one end had been totally killed out by Toxoptera, and learned from the owner that this area exactly corresponded with that of a small patch of oats which the previous year had failed to produce more than a very poor crop and had been plowed under without cutting. In preparing the ground for wheat in the fall of 1906, a volunteer growth of oats was reported to have sprung up on this area after plowing. Again the same observer, a little later in the season, found that the regularity of the occurrence of these spots in rows across a field, in northern Oklahoma, exactly corresponded to the location in this same field the previous summer of oat shocks, which had been allowed to stand out through a period of wet weather; the volunteer grain having sprung up there later in the season and remained growing amongst the young wheat in the fall. In Texas the relation of this volunteer growth in the fields, in autumn and early winter, to the abundance of Toxoptera does not appear to differ materially from what is known to occur elsewhere. When the secretary of the Texas Grain Dealers' Association first appealed to the Government for aid in investigating the pest, particular attention was directed to the possibility that methods might be devised for its control by spraying or otherwise treating the spots in grain fields, for the purpose of checking its ravages before these infested spots had increased in size and before the pest had spread from them over the entire field.

Thus it will be seen that primarily infestation is first invited by the volunteer growth starting up in cultivated fields in autumn. If such fields are sown to wheat or oats in the fall, the pest spreads from this earlier growth to the younger and more tender grain. This will of itself suggest several entirely practical cultural methods likely to restrict and prevent the development of the pest in the fields in autumn.

Crop rotation could scarcely fail of giving beneficial results. The destruction of all volunteer grain springing up in fields from which grain has been removed at thrashing gives promise of the greatest relief. Indeed, if careful attention were given to all fields in autumn, and all of this volunteer growth were destroyed before any grain whatever was sown, it is doubtful if such serious ravages as have occurred in the past could be repeated. This can all be accomplished by close pasturing and careful late plowing, followed as soon as possible by seeding.

At Hooker, Okla., the junior author found affected spots both on land that had been devoted to oats the previous year and on land that had previously grown cowpeas. This, as well as some other observations made by other parties, indicates that some of the grasses will have the same effect in inviting attack as volunteer grain growing up in the fields in the fall.

It is therefore most urgently recommended, and especially for the South, that all of this volunteer growth of whatever nature be completely killed out in the fields before seeding the following crop. Not only will this mode of procedure benefit especially the southern grain grower, but in the light of our present knowledge of the pest, it will serve as a protection to the spring oats crop over a large area of country where it is doubtful if serious ravages would occur at all were there not myriads of the pest continually developing to the South and drifting northward in spring with the advance of the season.

Following along the same line, attention should be directed to the probability that late seeding may prove a preventive of attack, for the reason that the pest will obviously gain less of a foothold in a late-sown field than it will where there has been an early growth of young grain plants. In other words, there is a likelihood that the pest may break out in spots, as has been several times previously noted, and to this extent late seeding is an advantage. However, this would be a serious disadvantage if the fields should afterward be overrun by hordes of migratory winged viviparous females in spring, for in this case the earlier sown and therefore the older and less succulent growth would suffer least from their attack. This is shown by the fact that late-sown and winter-pastured fields in Oklahoma suffered most in 1907. It must also be noted that at Winston-Salem, N. C., in April 1, 1907, wheat that had been sown about or a little prior to November 15, on ground free from young growth of volunteer grain, or the grasses, was practically uninfested even though located in the immediate vicinity of other badly infested fields sown earlier on ground more or less foul with young growth. All of this indicates pretty clearly that if all volunteer growth were eliminated in the fall, and the grain sown late, the pest would not become destructive. Of course the amount of benefit secured will depend upon the uniformity with which this method is carried into effect in any locality.

Over the northern part of the country where the insect passes the winter largely or wholly in the egg state, another measure can be applied to great advantage. The junior author has found that blue grass (Poa) is not only a summer food plant, but that it is very largely upon this grass that the eggs are deposited in the fall, and from which the offspring of the stem mothers make their way to the grain fields in spring. He has observed cases where the portion of a grain field bordered by bluegrass was the most seriously affected part of the entire field. If, then, roadsides, fence corners, and other waste lands were closely grazed in fall, winter, or early spring, these eggs would be largely destroyed and the food supply of the stem mother and her progeny cut off. This can always best be done during mild winters on account of a lack of snow. Where close pasturing is not practicable, burning over during the same season will have a similar if not an even more drastic effect.

ARTIFICIAL INTRODUCTION OF PARASITES.

As *Aphidius testaceipes* destroyed such hordes of Toxoptera in apparently very short periods of time, after they had once become established, we thought it possible materially to aid in this destruction by introducing the parasites artifically into localities where they were apparently absent. As Mr. C. N. Ainslie was unable to find any evidence of parasitization in the fields about Wellington, Kans., on April 1, 1907, it was decided to begin operations there. Accordingly, on April 9, over a bushel of wheat leaves that were almost covered with parasitized Toxoptera were collected at Kingfisher, Okla. Mr. Ainslie took charge of this material, and on April 10, made a careful survey of the fields about Wellington, Kans., to determine the situation relative to Toxoptera infestation, and on the morning of April 11 he scattered a portion of this material in one of the most badly infested fields that could be found in that vicinity, the remainder being left sheltered by the box lids. At this time he could find parasitized Toxoptera already in the fields, both the dead leathery bodies and those showing the characteristic yellow color. The parasites included in this introduction were roughly estimated at 2,500,000; this number, however, was probably not a "drop in the bucket" to those already in the field. If there were only one or two parasitized Toxoptera to a leaf, when a whole field is considered 2,500,000 would seem to be a very small number. So far as published records show this was the first artificial introduction of parasites into Kansas.

April 12 another lot of parasitized material, sent Mr. Ainslie by the junior author from Kingfisher, which was fully as large as the previous consignment, was introduced into another field 2 miles from the first. All of this material, originally intended for one field, was reported as one experiment by the junior author and appeared as one experiment in Circular 93, since Mr. Ainslie's notes were not on file in the office at the time. We find, however, that Mr. Ainslie,

on his own initiative, conducted two separate experiments, thus rendering the results twice as valuable.

April 18 a minor introduction of parasites was made at McPherson, Kans., and on April 21 there was another similar one at Sterling, Kans. Parasitized "green bugs" were observed present at each place on these dates.

Mr. Ainslie remained in the vicinity of Wellington, and more briefly at McPherson and Sterling, for the purpose of making accurate observations on the effect of these introductions.

Two weeks later, on visiting the two fields at Wellington, where the first introduction had been made, Mr. Ainslie found that on account of the cold weather the effect upon the parasites was almost the same as though they had been kept in cold storage. Some of those sheltered by the box lids had issued, but had apparently not ventured far from their shelter and were found in a semitorpid condition capable of little movement. The percentage of parasitism from Aphidius appeared to be the same in all other fields in this locality, irrespective of these introductions, except close about the box lids, where they seemed a little more numerous, the conditions of parasitization generally being about the same as had existed two weeks previous. The Toxoptera, however, had greatly increased in numbers, and the fields were now plainly showing the effects of their work.

Subsequent examinations of fields at Wellington showed that after the weather warmed up in May the parasites speedily overcame the Toxoptera and that the fields where these artificial introductions were made had suffered as much as any fields in the neighborhood from attack by the "green bug." All of this seems to indicate that no noticeable good resulted from these introductions, which, in the light of our present knowledge, is not at all surprising. The minor experiment at McPherson was also reported upon to us by Mr. W. Knaus, and his report was in accord with our own observations.

On May 17 an artificial introduction of parasites was begun at Manhattan, Kans.[1] While this experiment bore out our former observations, the results obtained here should not bear as much weight as the earlier introductions, since the Toxoptera was already nearly overcome when the introduction was begun.

When one stops to consider the numerous and varied hosts of *Aphidius testaceipes*, its manner of hibernation, its wide distribution, and the higher temperature required for its development over and above that needed by its host; also the fact that it may readily be transported along with its host as adults, or within the body of the latter, one can readily see the futility of attempting materially to increase its numbers or efficiency by artificial introduction into grain fields.

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[1] Cir. 93, Bur. Ent. U. S. Dept. Agr., pp. 10–12, Aug. 22, 1907; Cir. 93, revised, Bur. Ent., U. S. Dept. Agr., pp. 12–13, June 23, 1909.

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